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US Army Corps of Engineers
Waterways Experiment Station

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Hydraulic Model Investigation

by Ronald T. Wooley

Prepared for U.S. Army Engineer District, Pittsburgh

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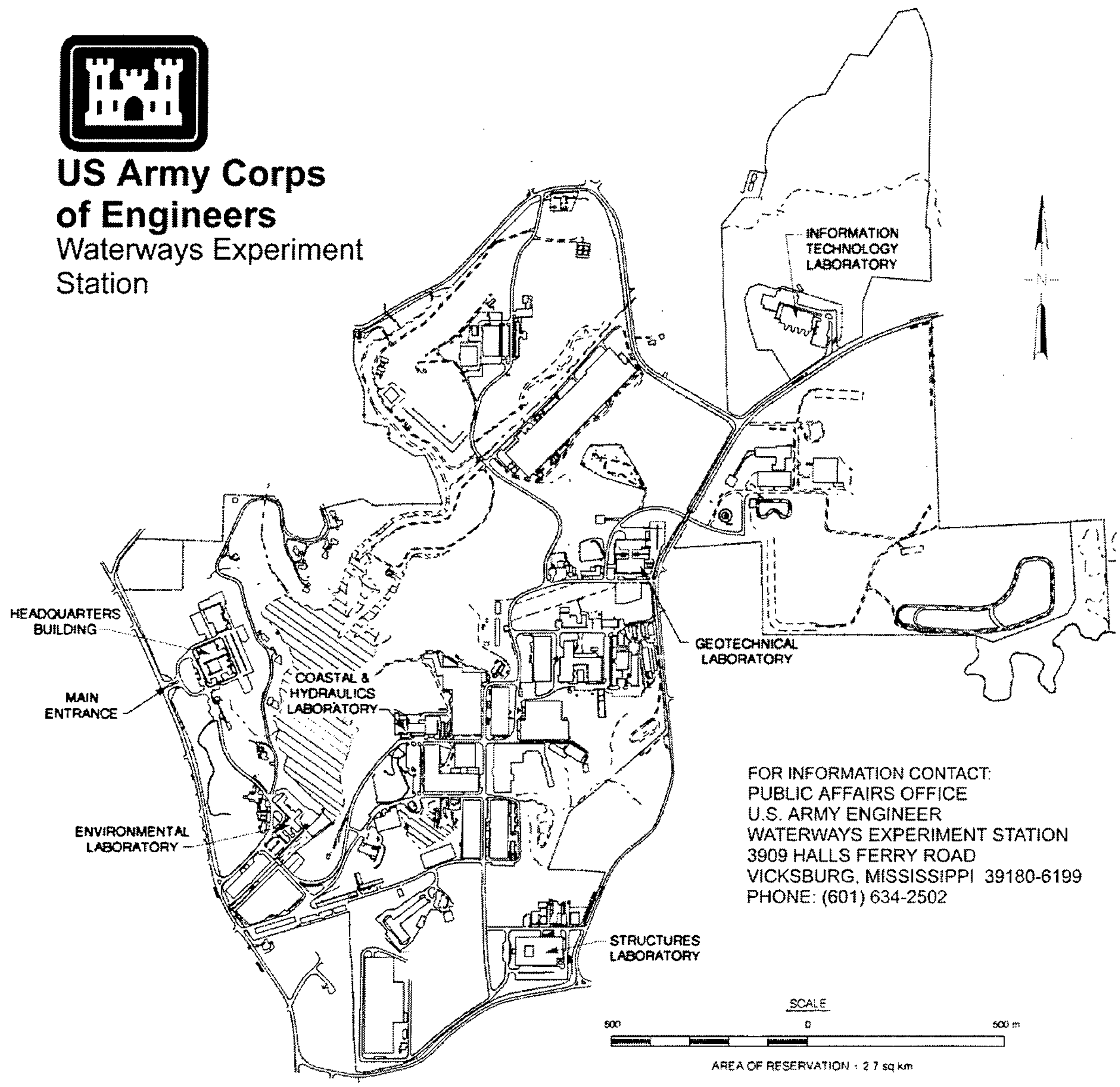

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Preface

The model investigation reported herein was conducted for the U.S. Army Engineer District, Pittsburgh (ORP), by personnel of the Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station (WES). The study was conducted during 1985 to 1989.

During the course of the model study, representatives of ORP; the U.S. Army Engineer Division, Ohio River; Headquarters, U.S. Army Corps of Engineers; and other navigation interests visited WES at different times to observe special model experiments and to discuss the results of those experiments. ORP was informed of the progress of the study by monthly progress reports and special reports at the end of each experiment.

This report is being published by the WES Coastal and Hydraulics Laboratory (CHL). The CHL was formed in October 1996 with the merger of the WES Coastal Engineering Research Center and the Hydraulics Laboratory. Dr. James R. Houston is the Director of the CHL, and Messrs. Richard A. Sager and Charles C. Calhoun, Jr., are Assistant Directors.

The first-line review of this report was conducted by Mr. T. J. Pokrefke, Acting Chief of the Navigation Division. The principal investigator in immediate charge of the model study was Mr. R. T. Wooley, assisted by Messrs. E. Johnson, E. A. Frost, and J. W. Sullivan and Ms. D. P. George, all of the Navigation Division. This report was prepared by Mr. Wooley.

Director of WES during preparation and publication of this report was Dr. Robert W. Whalin.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
degrees (angle)	0.01745329	radians
feet	0.3048	meters
miles (U.S. statute)	1.609347	kilometers
square miles	2.589998	square kilometers

1 Introduction

Location and Description of Prototype

The Monongahela River (Figure 1) is formed by the confluence of the Tygart and West Fork Rivers at Fairmont, WV, and flows in a northerly direction, joining with the Allegheny River at Pittsburgh, PA, to form the Ohio River. The river drains an area of 7,386 square miles[1] and drops a total of 147 ft in its 128.7-mile length. Point Marion Lock and Dam are on the Monongahela River at river mile 90.8, approximately one mile upstream of Point Marion, PA. The reservoir, with normal upper pool el 797.0[2], extends approximately 11.2 miles upstream to Morgantown Lock and Dam.

The existing Point Marion project consists of a nonnavigable structure with six crest gates having a clear span of 60 ft between 10-ft-wide piers. A 62-ft-long overflow weir with a crest elevation of 796.7 connects the gated structure to the right bank abutment. A 56-ft-wide by 350-ft-long navigation lock is located along the left bank of the river.

History of Navigation Improvements on the Monongahela River

The original navigation system on the Monongahela River consisted of seven locks and dams extending upstream to Greensboro, PA. The system was reconstructed between 1902 and 1932, resulting in 15 navigation structures from Pittsburgh to Fairmont. Starting in 1950, redevelopment of the Monongahela River replaced Locks and Dams 10 and 11 with a single structure at Morgantown; replaced Locks and Dams 12, 13, 14, and 15 with the Hildebrand and Opekiska projects; permitted Lock and Dam 5 to be removed with the

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[1] A table of factors for converting non-SI units of measurement to SI units is found on page vii.
[2] All elevations (el) cited herein are in feet referred to the National Geodetic Vertical Datum (NGVD).

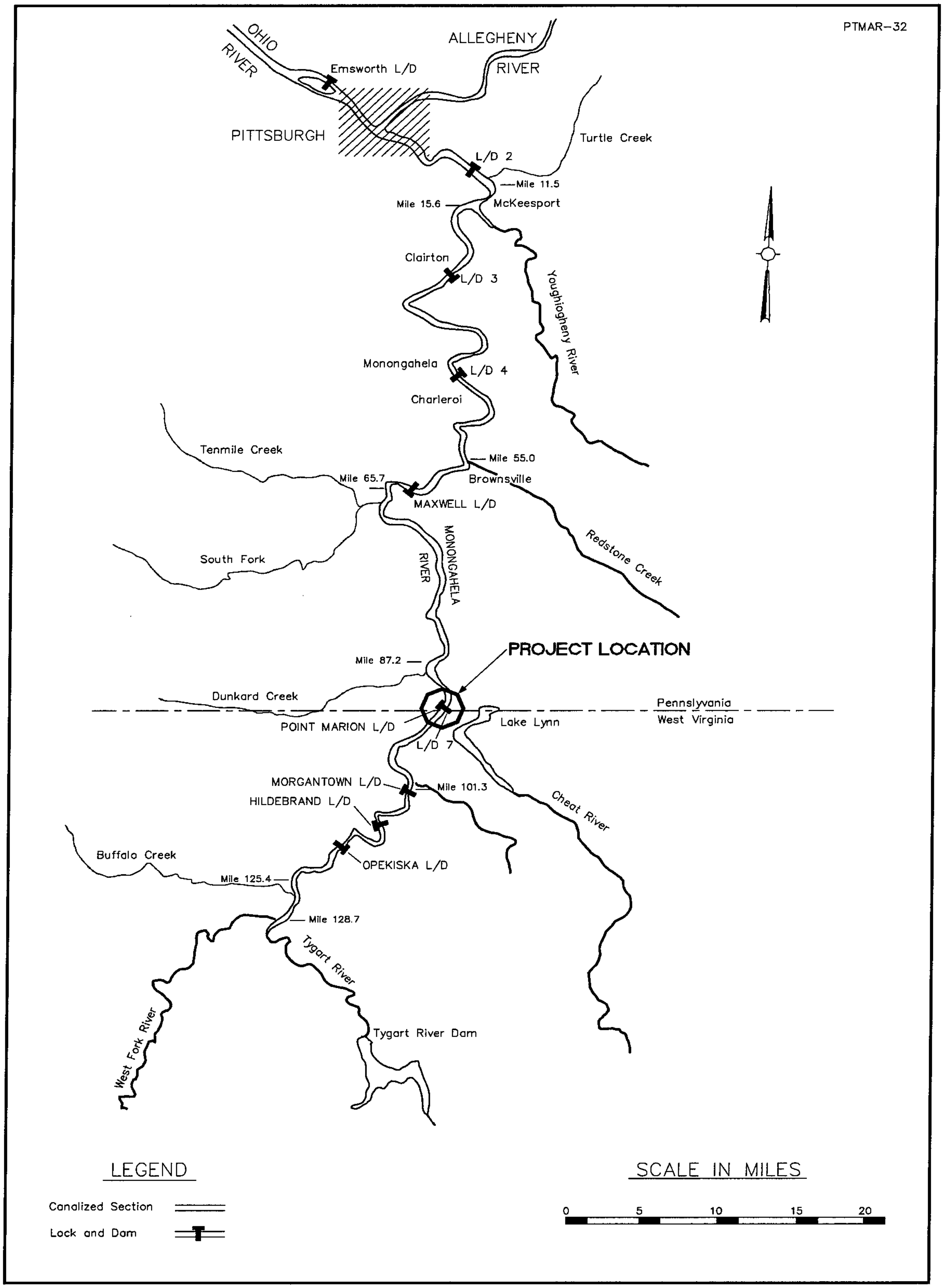


Figure 1. Location map

construction of a new Dam 4; and replaced Dam 6 with Maxwell Lock and Dam. Structures still unimproved include Locks and Dams 2, 3, 7, and 8 and Lock 4.

The Point Marion lock is on the left descending bank in Greene County, PA, and the dam ends at an abutment on the right bank in Fayette County, PA. It was originally constructed by the U.S. Government in 1923-1926. The project has been operated and maintained since 12 October 1925. In 1958-1959, the dam was modified to provide a gated structure and raise the upper pool by 4 ft to the present elevation of 797.0.

Conditions of Existing Structures

Concrete damage is very extensive on all exposed surfaces of the guide, guard, and lock walls. Structural cracks exist at the thin, unreinforced wall sections of valve and bulkhead recesses, at gate anchorages, and at corners of openings and recesses. The lock walls and sills are founded on a weak, indurated clay layer underlaid by a thin coal seam. The strength parameters of these materials, as determined by experiments conducted at the U.S. Army Engineer Waterways Experiment Station, are extremely low. A stability investigation of representative land wall, river wall, and lock sill monoliths indicates unsafe conditions. Valves, miter gates, and embedded metal have extensive deterioration due to corrosion and normal wear and use.

The concrete in the piers of the dam and service bridge is in generally good condition. However, exposed concrete remaining from the original dam is in poor condition, with cracks and extensive spalling. Sections of the original dam, incorporated as gate sills for the present dam, and the piers of the existing dam fail to meet sliding stability criteria. Areas of scour immediately below the dam are also evident and could eventually lead to more serious stability problems. The abutment monoliths are unsafe due to inadequate resistance to overturning and sliding. The abutment concrete is in very poor condition and requires extensive repair.

Present Development Plan

The plan for improvement for Point Marion Lock and Dam consists of a new navigation lock with clear chamber dimensions of 84 ft wide by 720 ft long to be constructed landward of the existing lock. The existing lock would be removed, and the dam would be connected to the new lock by a 115-ft section comprising a 110-ft-long overflow weir with a crest elevation of 796.5 and a 5-ft-long section adjacent to the first dam pier with a top elevation of 805.0. A new right bank abutment would replace the present deteriorated structure. The existing gated dam would be upgraded. This rehabilitative effort would consist of repairing the spalled downstream face of the gate sills and the cracks around the service bridge seats and anchoring the piers and gate sill monoliths of the dam

into firm rock with prestressed rock anchors. The concrete of the existing 65-ft fixed weir adjacent to the abutment would be repaired and additional stone protection provided downstream. A new abutment, to replace the present deteriorated structure, would be constructed on the right bank and located with the river face 30 ft riverward of the existing abutment. The new abutment would replace 30 ft of the existing fixed crest weir, leaving 35 ft of weir between the new abutment and the dam.

Purpose of Model Study

The general design of the Point Marion redevelopment project was based on sound theoretical design practice and experience with similar projects. However, conditions through the reach and approaching and leaving the lock could be expected to be extremely complex because of the effect of currents, irregular channel alignment and configuration, limited channel width, high velocities, and crosscurrents. Navigation conditions vary with location and flow conditions upstream and downstream of a structure, and an analytical study to determine hydraulic effects expected to result from a particular design is both difficult and inconclusive. With the proposed modifications to the existing structures, a comprehensive model study was considered necessary to investigate conditions that would develop through the reach, to develop solutions to ensure satisfactory navigation conditions, and to demonstrate to design engineers and navigation interests the conditions that would result from various plans and modifications.

2 The Model

Description

The scale model reproduced about 2.1 miles of the Monongahela River channel and adjacent overbank, from mile 90.0 to mile 92.1, with lock and dam structures. The model reproduced about 6,000 ft upstream and 4,400 ft downstream of Point Marion Dam. Channel and overbank areas were molded in sand-cement mortar to sheet metal templates in the fixed-bed type model. Portions of the model where changes in lock alignment and channel configurations were considered or could be anticipated were molded in pea gravel to allow for easy modification. The lock, dam crest, piers, guard walls, and guide walls were built from sheet metal.

The channel portion of the model was molded to conform to a 1966 hydrographic survey, and the overbank areas were molded to a 1966 topographic survey. The overbank area was constructed to a grade sufficient to confine the maximum riverflow of interest to the U.S. Army Engineer District, Pittsburgh.

Scale Relations

The model was built to an undistorted scale of 1:100, model to prototype, to effect accurate reproduction of velocities, crosscurrents, and eddies affecting navigation. Other scale ratios resulting from the linear scale ratio are as follows:

Characteristic	Dimension[1]	Scale Relationship Model:Prototype
Area	$A = L_r^2$	1:10,000
Velocity	$V = L_r^{1/2}$	1:10
Time	$T = L_r^{1/2}$	1:10
Discharge	$D = L_r^{5/2}$	1:100,000
Roughness (Manning's n)	Manning's $n = L_r^{1/6}$	1:2.15

[1] Dimensions are in terms of length L

Measurements of discharges, water-surface elevations, and current velocities can be transferred quantitatively from model to prototype equivalents using these relations.

Appurtenances

Water was supplied to the model by a 10-cfs pump operating in a recirculating system. The discharge was controlled and measured at the upper end with a valve and venturi meter. Water-surface elevations were measured by piezometer gauges located in the model channel and connected to a centrally located gauge pit. A slide-type tailgate was provided at the lower end of the model to control the tailwater elevations downstream of the dam, and slide-type gates in the spillway were used to control the upper pool elevation.

Velocities and current directions were measured in the model by cylindrical wooden floats submerged to the depth of a loaded barge (9-ft prototype). Confetti and dye were also used to determine current patterns in eddies. A miniature current meter measured spot velocities. A radio-controlled model tow and towboat, equipped with twin screws, Kort nozzles, and forward and reverse rudders, and powered by a small electric motor operating from batteries in the tow, were used to study and demonstrate the effects of currents on navigation. The tow in the study represented six 195-ft-long by 35-ft-wide standard barges with a 100-ft-long pusher. This provided an overall size tow of 685 ft long by 70 ft wide loaded to a draft of 9 ft. The towboat operated in forward or reverse, at various speeds, and with variable rudder settings. It was calibrated to the speed of a comparable size prototype towboat moving in slack water and operated at 1 to 2 miles per hour above the speed of the currents to maintain rudder control but not overpower the currents. Multiple-exposure photographs recorded the path of the tow with the various conditions (Figure 2).

Model Adjustment

Prototype current directions and velocities were not available for model adjustment; therefore, current patterns at the entrance to the model were adjusted to reflect normal patterns that occur with the channel configuration reproduced. The surface of the model was constructed of brushed cement mortar to provide a roughness (Manning's n) of about 0.0135, which corresponds to a roughness in the prototype of about 0.029. With the model simulating the proposed original design, water-surface elevations were measured in the model with various riverflows and checked against a tailwater rating curve supplied by the Pittsburgh District. The results indicated that the model reproduced the tailwater rating curve with a reasonable degree of accuracy and was adequate for the model study.

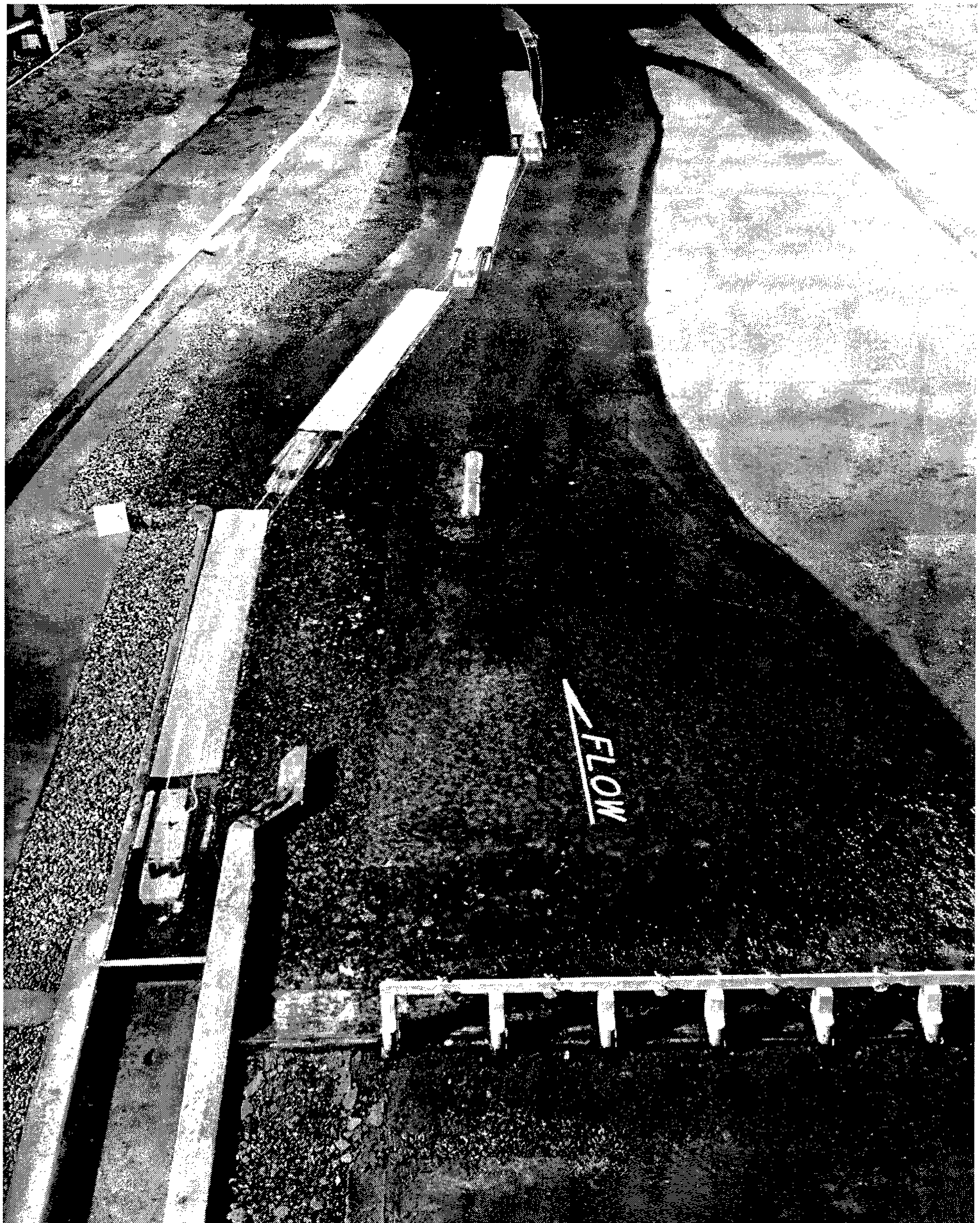


Figure 2. Path of tow with various conditions

3 Experiments and Results

Experiments were concerned primarily with the study of flow patterns, measurements of velocities and water-surface elevations, and the effects of currents on the movement of the model tow into the lock approaches during navigable river flows.

Procedures

A selection of representative riverflows were used for the experiments, based on information furnished by the Pittsburgh District, as follows:

a. A controlled 22,500-cfs riverflow with normal upper pool el 797.0 and tailwater el 788.5.

b. An uncontrolled 33,000-cfs riverflow with normal upper pool el 797.2 and tailwater el 792.0.

c. An uncontrolled 55,000-cfs riverflow with tailwater el 796.8 (maximum navigable flow for experiments).

d. An uncontrolled 66,000-cfs riverflow with tailwater el 799.1.

e. An uncontrolled 92,000-cfs riverflow with tailwater el 802.8.

f. An uncontrolled 104,000-cfs riverflow with tailwater el 804.3.

g. An uncontrolled 133,000-cfs riverflow with tailwater el 807.7.

Base Experiments (Original Design)

Description

Base experiments were conducted with the model reproducing the original design as shown in Figures 3-5. These experiments provided information and

data that could be used to evaluate the effects of proposed modifications on water-surface elevations, current direction and velocities, and navigation conditions. The principal features reproduced or simulated in the model, shown in Figures 3-5, included the following:

a. A 490-ft nonnavigable gated spillway including six 70- by 8.5-ft tainter gates and seven 10-ft-wide piers. The dam was connected to the right bank by a 35-ft-long fixed crest weir with a crest el of 795.7 and a 30-ft-long abutment with top el 805.0.

b. A new lock with clear chamber dimensions of 84 ft wide by 720 ft long constructed in the left bank adjacent to the existing lock. The top of the lock walls were at el 803.0. The new lock was 115 ft landward of and parallel to the first pier of the dam.

c. A 710-ft-long ported guard wall with seventeen 25-ft-diam cells spaced 40 ft on centers (Figure 5). This provides eighteen 15-ft-wide port openings with top of ports at el 792.0. The forebay of the lock was excavated to el 782.0 from the lock chamber upstream to sta 8+15A and sloped up on a 1V:20H slope to tie into the channel excavation. This provided 10-ft-high ports along most of the wall. The top of the guard wall was el 803.0.

d. A 700-ft-long solid lower guide wall extending downstream from the landside lock wall with top el 803.0. The effective length of the guide wall measured from the downstream end of the riverside lock wall is 380 ft.

e. Removal of the existing lock and replacement with a 110-ft-long fixed-crest overflow weir with crest at el 796.5 abutting the new lock and a 5-ft-long section with top el 805.0 abutting the first dam pier.

f. Excavation of the left bank on a 1V on 2H slope to provide a navigation channel into the upper lock approach. The upper approach channel was excavated to el 785.0 along a line extending upstream from the river face of the landside lock wall. This provided a navigation channel width of 90 ft at the upstream end of the guard wall.

g. Excavation of the lower lock approach to el 765.0. A turning basin was provided landward of the lower guide wall to allow additional stern clearance for a tow turning toward the main river channel, and the left bank was reshaped downstream to sta 32+08

Results

Water-surface elevations. Water-surface elevations obtained with original design conditions are shown in Table 1. These data indicate that the slope in

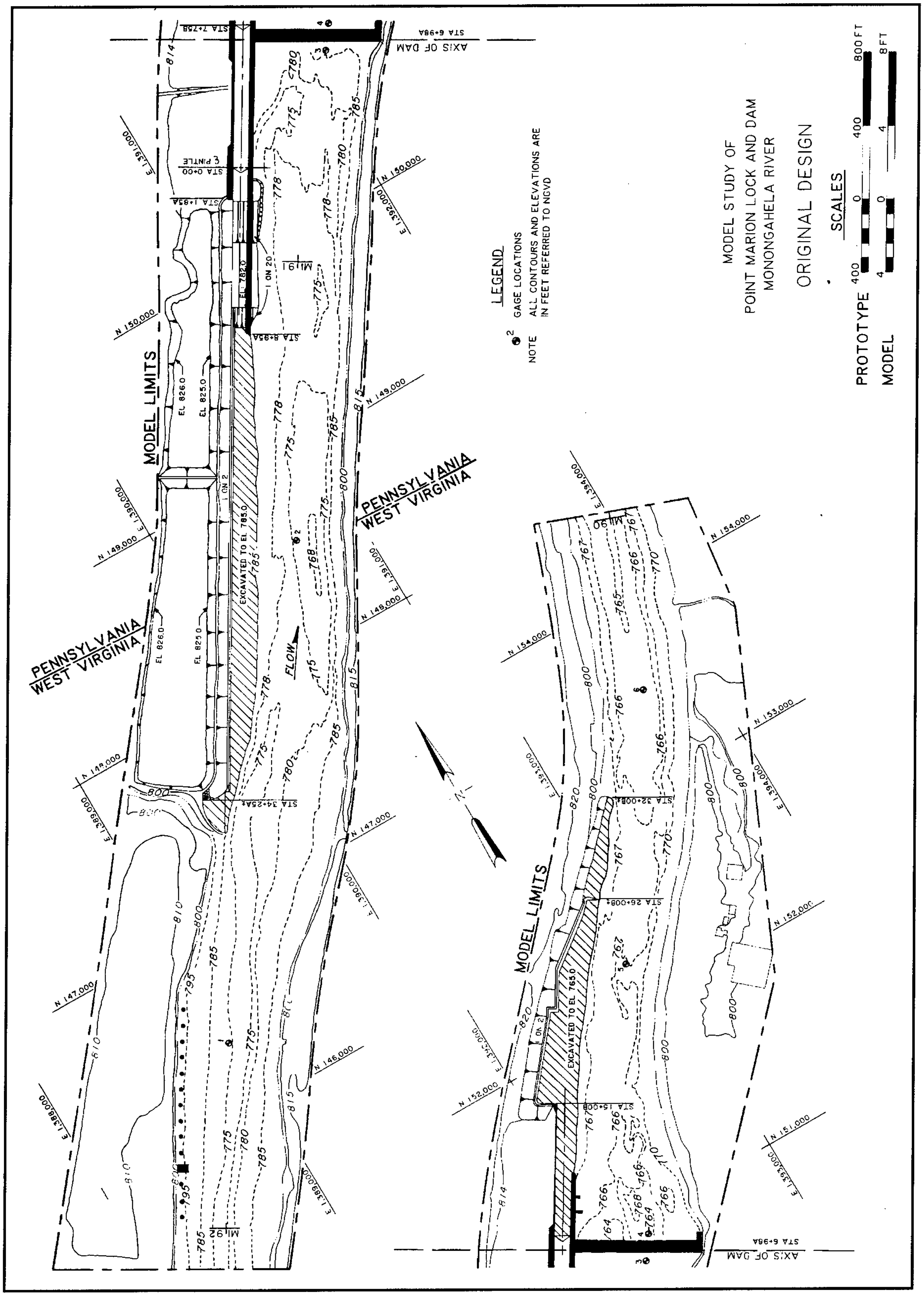


Figure 3. Original design

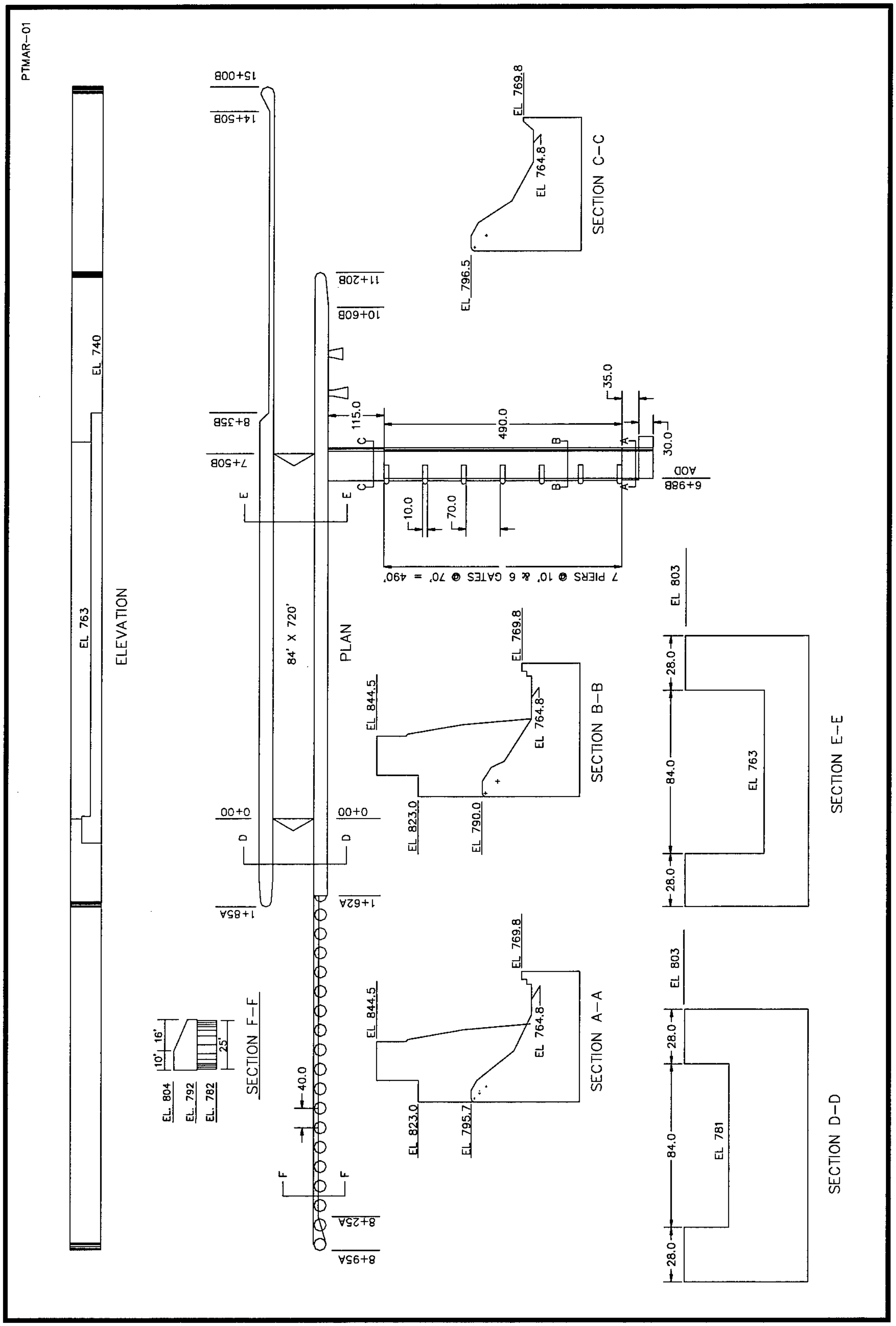


Figure 4. Original design, plan and sections

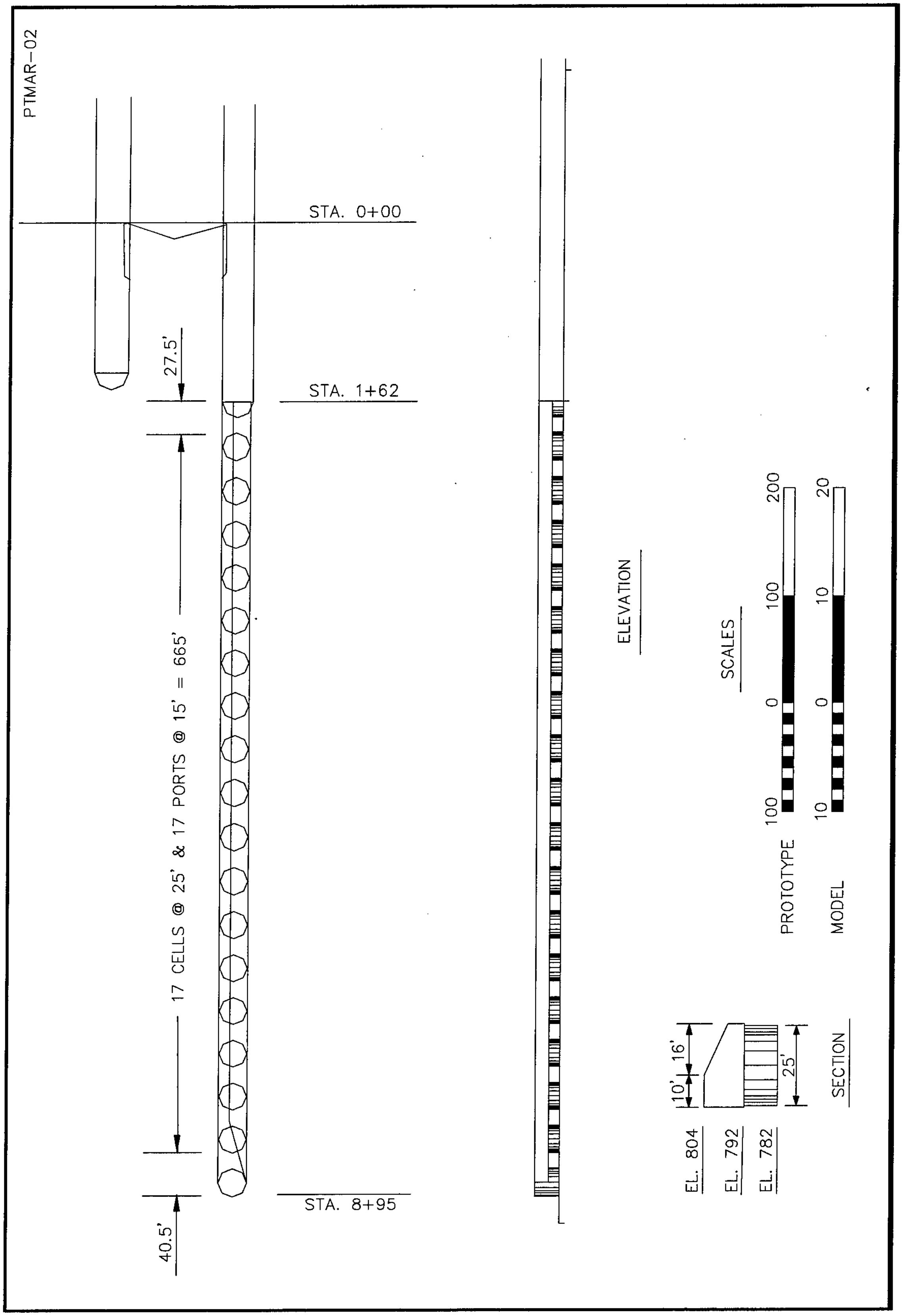


Figure 5. Upper guard wall, plan and section

water-surface elevation varied from about 0.2 to 0.6 ft per mile upstream of the dam with the 22,500- and 92,000-cfs riverflows, respectively, and from about 0.1 to 0.4 ft per mile downstream of the dam with the 22,500- and 133,000-cfs riverflows, respectively. With uncontrolled riverflows, the drop across the dam varied from 7.8 to 1.8 ft with the 33,000- and 133,000-cfs riverflows, respectively.

Table 1
Water-Surface Elevations, Base Experiment (Original Design)

Gauge No.	Water-Surface Elevations for Discharge in 1,000 cfs						
	22.5	33	55	66	92	104	133
1	797.2	798.4	801.2	802.5	805.9	807.2	810.3
2	797.1	798.3	801.1	802.4	805.8	807.1	810.2
3	797.0[1]	798.0	800.7	802.1	805.3	806.7	809.9
4	788.6	792.2	797.0	799.3	803.1	804.6	808.1
5	788.5	792.1	796.9	799.2	803.0	804.5	807.9
6	788.5[1]	792.0[1]	796.8[1]	799.1[1]	802.8[1]	804.3[1]	807.7[1]

[1] Controlled elevation.

Current directions and velocities. Current direction and velocities obtained with the original design are shown in Plates 1-3. Current patterns upstream and downstream of the dam for the 55,000-cfs riverflow are shown in Photos 1 and 2. These data indicate that the current was generally parallel to the left descending bank from the upstream end of the model to the upper approach of the lock. As the flow approached the lock, some flow moved around the upstream end of the guard wall. A small counterclockwise eddy formed in the upper lock approach near the entrance to the lock. The maximum velocities of the current in the navigation channel varied from about 4.4 to 7.3 fps near the upstream mooring area, 3.5 to 6.8 fps about 2,000 ft upstream of the guard wall, and 1.5 to 3.6 fps near the upstream end of the guard wall with the 22,500- and 55,000-cfs riverflows, respectively. Alignment of the right bank downstream of the dam caused the flow to pass through the dam and move toward the left bank and into the lower approach of the lock (Photo 2). With the 22,500-cfs riverflow, a large counterclockwise eddy formed immediately downstream of the weir between the dam and the new lock, and extended into the navigation channel and along the land-side guide wall. The maximum velocity of currents moving into the lower approach of the lock ranged from 3.6 to 4.2 fps with the 22,500- and 33,000-cfs riverflows, respectively. As the riverflow increased to 55,000 cfs and the level of the upper pool increased, flow over the weir between the dam and the lock tended to reduce the size and intensity of the eddy immediately downstream of the weir and reduce the angle of the currents moving across the lower approach. The maximum velocities of the current in the

navigation channel downstream of the lock varied from 3.0 to 4.9 fps about 2,000 ft downstream of the dam and 2.9 to 4.6 fps about 4,000 ft downstream of the dam with the 22,500- and 55,000-cfs riverflows, respectively.

Navigation conditions. Navigation conditions were hazardous for downbound tows approaching the new lock with the maximum navigable flow of 55,000 cfs. The navigation clearance for a tow approaching the lock was minimal (approximately 20 ft of total clearance between the tow and the bank or the guard wall). A downbound tow entering the reach 50 ft riverward of the left bank could navigate along the left descending bank and enter the lock approach (Photo 3). However, any error in alignment would result in the tow either grounding on the left bank or being moved riverward of the upper guard wall (Photo 4). A downbound tow entering the reach from midchannel could not drive to the left bank and align with the lock approach a safe distance upstream of the guard (Photo 5). There was no indication of major difficulties for upbound tows leaving the new lock, but the clearance between the tow and the bank or guard wall was minimal (Photo 6). In the lower lock approach, there was a tendency for the current moving across the lock approach to push a downbound tow into the left bank as it moved out of the lock chamber. Considerable time and maneuvering were required for the towboat to rotate the head of the tow away from the left bank and drive into the main river channel (Photo 7). Upbound tows could make the turn from the main river channel and approach the downstream end of the guide wall without any difficulty (Photo 8). However, as the tow moved upstream toward the lock chamber, the eddy near the lock tended to move the entire tow away from the guide wall and out of alignment with the lock chamber. There was a strong tendency for the tow to be moved into the downstream end of the guard wall, and considerable maneuvering was required for the tow to align with and enter the lock chamber.

Original Design-Modified

Description

Original Design-Modified (Figure 6) was the same as the original design, except the excavation for the upper approach channel was increased by widening the channel at the upper end of the guard wall to provide a 158-ft-wide channel at navigation depth. The upper approach was excavated along a line extending upstream from the river face of the landside lock wall to a point 142 ft landward of the upstream end of the guard wall and then to a point 42 ft landward of the center line of the lock at sta 33+25A. This provided a slightly wider navigation channel than the original design for the tow to turn into from the main river channel. This plan was an effort to provide satisfactory navigation conditions for downbound tows approaching the lock while minimizing excavation of the left bank.

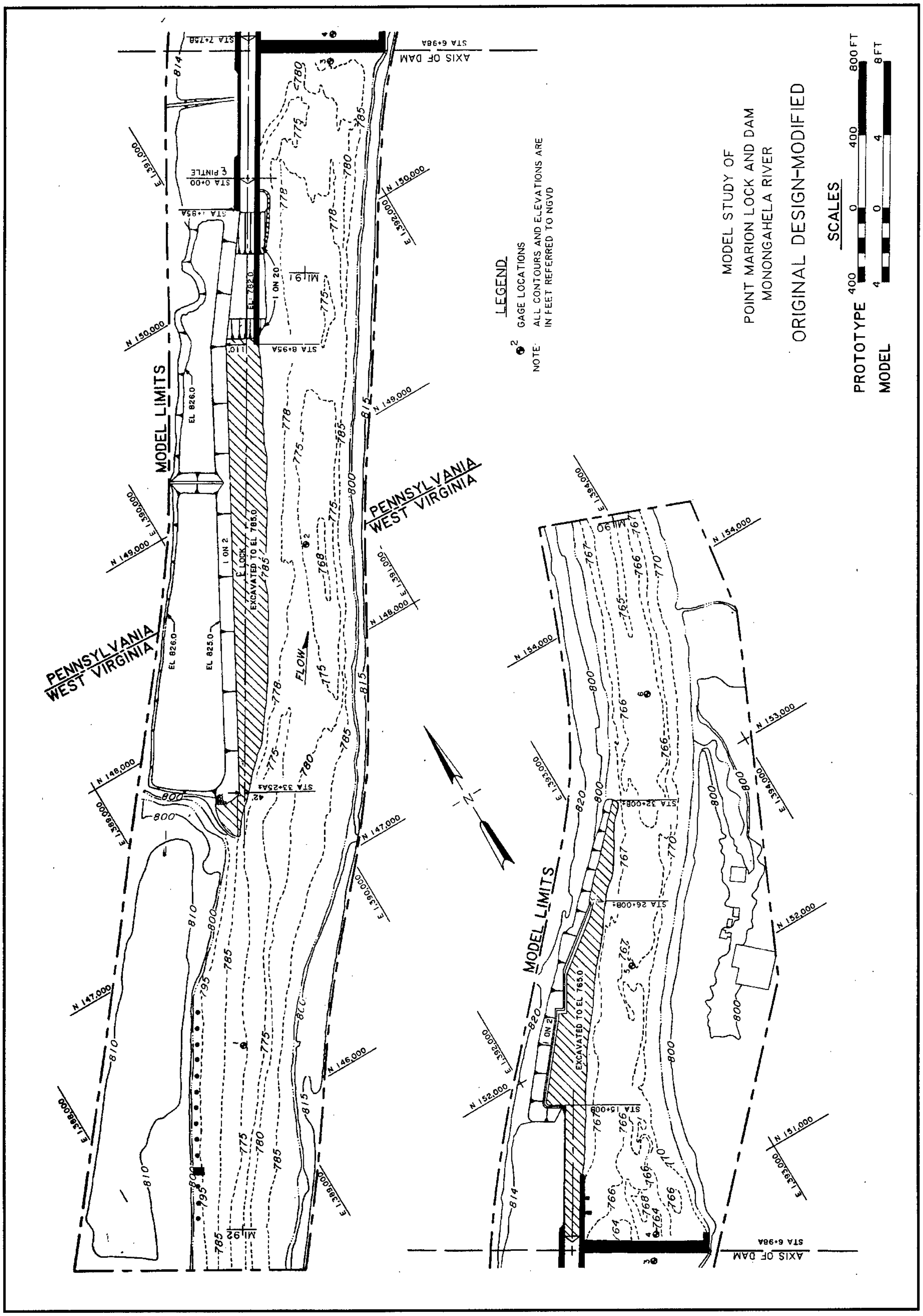


Figure 6. Original Design-Modified

Results

Water-surface elevations. Water-surface elevations obtained with original design-modified conditions are shown in Table 2. These data indicate no changes in water-surface elevation compared with the original design.

Table 2
Water-Surface Elevations, Original Design-Modified

Gauge No.	Water-Surface Elevations for Discharge in 1,000 cfs						
	22.5	33	55	66	92	104	133
1	797.2	798.4	801.2	802.5	805.9	807.2	810.3
2	797.1	798.3	801.1	802.4	805.8	807.1	810.2
3	797.0[1]	798.0	800.7	802.1	805.3	806.7	809.9
4	788.6	792.2	797.0	799.3	803.1	804.6	808.1
5	788.5	792.1	796.9	799.2	803.0	804.5	807.9
6	788.5[1]	792.0[1]	796.8[1]	799.1[1]	802.8[1]	804.3[1]	807.7[1]

[1] Controlled elevation.

Current directions and velocities. Current direction and velocities upstream of the dam obtained with the Original Design-Modified are shown in Plate 4. These data indicate a slight decrease in the velocity of the currents in the navigation channel upstream of the dam due to the increase in cross-sectional area provided by the increased excavation along the left bank. The maximum velocities of the currents in the navigation channel varied from about 4.1 to 7.1 fps near the upstream mooring area, 2.9 to 6.2 fps about 1,500 ft upstream of the guard wall, and 1.4 to 2.9 fps near the upstream end of the guard wall with the 22,500- and 55,000-cfs riverflows, respectively.

Navigation conditions. Navigation conditions were improved with the 22,500-cfs riverflow because of the increased width of the approach channel. A downbound tow could drive into the excavated channel, align with the left bank, reduce speed, and enter the lock forebay at a safe speed. However, with the 33,000- and 55,000-cfs riverflows, navigation conditions were unsatisfactory for downbound tows. A downbound tow could not drive to the left bank, align with the guard wall a safe distance upstream of the wall, and reduce speed to enter the lock forebay at a safe speed. There was a strong tendency for the tow either to turn too sharply into the excavation and run aground on the left bank or miss the lock approach and either strike the upper end of the guard wall or move riverward of the wall. No major problems were indicated for upbound tows leaving the upper lock approach. The channel width was sufficient for the tow to move away from the guard wall and move upstream without any tendency for the tow to ground on the left bank.

Preliminary experiments. Preliminary experiments were conducted with various dike arrangements in an effort to establish satisfactory navigation conditions with the limited left bank excavation of this plan. A series of dikes were placed along the right bank at various locations and spacing in an effort to move the current into the left bank excavation and improve navigation conditions. A series of dikes were also placed along the left bank upstream of the excavation in an effort to provide a protected area for the tow to make its turn into the excavation. These preliminary experiments indicated dikes could not establish satisfactory navigation conditions with this plan.

Plan A

Description

Because of the depth along and the alignment of the left bank in the vicinity of the mooring cells near the upstream end of the model, the model tow could not navigate close to the left bank. The model in this area was not considered to be critical at the time of construction and was not covered by the hydrographic survey provided by the Pittsburgh District; therefore, the model upstream of sta 36+00 was constructed using the available overbank survey and a typical cross section of the bed contours. It became apparent that to make sound judgments relative to the approach conditions, it would be necessary to mold the upper reach to a prototype survey. The Pittsburgh District provided an existing prototype survey, and the upper reach of the model was remolded to conform to the survey.

Plan A (Figure 7) is the same as the original design except for the following:

a. The model upstream of sta 36+00, in the vicinity of the left bank mooring cells, was remolded to a more recent hydrographic survey provided by the Pittsburgh District. The survey provided navigation depth along the left bank in the vicinity of the mooring cells.

b. The left bank excavation was modified to provide additional channel width approaching the upper guard wall. The upper approach was excavated to along a line extended upstream from the land face of the landside lock wall to a point 120 ft landward of the center line of the lock at sta 33+25A. The excavation was then curved landward and tied into Crooked Run Creek, which enters the river immediately upstream of sta 33+25A. This provided a channel about 115 ft wide at the upstream end of the guard wall.

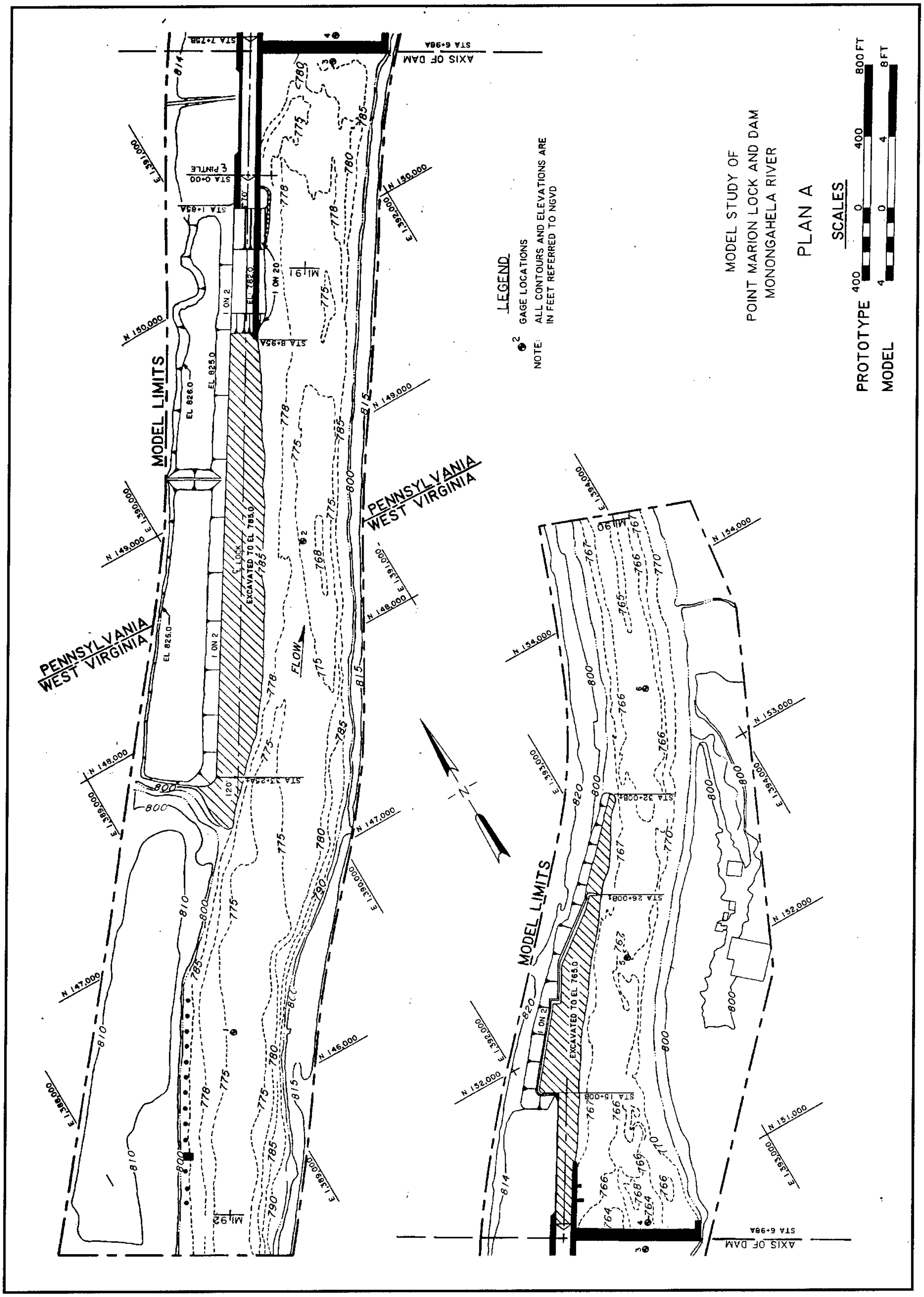


Figure 7. Plan A

Results

Water-surface elevations. Water-surface elevations obtained with Plan A are shown in Table 3. Compared with the Original Design-Modified (Table 2), these data indicate a slight increase (0.1 ft) in water-surface elevation at Gauge 1, which is located near the upstream end of the model and in the remolded section of the model, with the 22,500- and 33,000-cfs riverflows. With the 55,000-cfs riverflows, the water-surface elevation decreased about 0.2 ft at Gauge 2, which is located opposite the increased channel excavation. There were no changes in the drop across the structure or water-surface elevation downstream of the dam.

Table 3
Water-Surface Elevations, Plan A

Gauge No.	Water-Surface Elevations for Discharge in 1,000 cfs		
	22.5	33	55
1	797.3	798.5	801.2
2	797.1	798.3	800.9
3	797.0[1]	798.1	800.7
4	788.6	792.2	797.0
5	788.5	792.1	796.9
6	788.5[1]	792.0	796.8[1]

[1] Controlled elevation.

Current directions and velocities. Current directions and velocities obtained with Plan A conditions are shown in Plate 5. These data indicate a decrease in the velocities of the current through the upper reach of the model and a slight increase in the velocities of the current entering the lock forebay compared with the original design. The alignment of the currents was generally the same as those with the original design. The current tended to follow the left bank until it reached the excavated channel, where it then followed the old bank line for some distance downstream before it moved into the excavated channel. The maximum velocities of the current in the navigation channel varied from about 3.1 to 6.0 fps near the upstream mooring area, 2.9 to 5.6 fps about 2,000 ft upstream of the guard wall, and 1.3 to 3.1 fps near the upstream end of the guard wall.

Navigation conditions. Navigation conditions were improved with the lower flows (22,500 and 33,000 cfs) because of the increased width and alignment of the excavation. However, with all flows, the tow could not use the excavation channel near its upstream end because of the alignment of the bank upstream of sta 33+25A in the vicinity of the mooring cells. With this area remolded, the left bank upstream of sta 33+25A did not line up with the

excavated channel; therefore, a downbound tow could not navigate along the left bank and enter the upstream end of the excavation. With the maximum navigable flow of 55,000 cfs, a downbound tow could not leave the existing river channel, enter the excavated channel, align with the lock approach, reduce speed, and enter the lock forebay at a safe speed. There was a strong tendency for the tow either to turn too sharply into the excavation and run aground on the left bank or miss the lock approach and either strike the upper end of the guard wall or move riverward of the wall. No major problems were indicated for an upbound tow leaving the upper lock approach. An upbound tow could move away from the guard wall and navigate upstream without any difficulties.

Additional experiments. Preliminary experiments were conducted with various dike arrangements in an effort to establish satisfactory navigation conditions with the additional excavation of the left bank of this plan. A series of dikes were placed along the right bank at various locations and spacing in an effort to move the current into the left bank excavation and improve navigation conditions. A series of dikes were also placed along the left bank upstream of the excavation in an effort to provide a protected area for the tow to make its turn into the excavation. These additional experiments indicated dikes would not establish satisfactory navigation conditions with this plan.

Plan B

Preliminary experiments

The model was modified by changing the alignment of the left bank excavation upstream of the new lock. With this new alignment, preliminary experiments were conducted with various dike arrangements to develop a system of dikes that would assist tows in making the turn from the main river channel into the lock approach. These experiments indicated that spur dikes placed along the right bank would help downbound tows navigate into the lock. During these preliminary experiments, a vane dike was developed to provide some protection for tows entering and leaving the lower lock approach.

Description

Plan B (Figure 8) was the same as Plan A except for the following:

a. The alignment of the left bank excavation was changed to align with the existing bank in the vicinity of the upstream mooring cells. This represented the maximum excavation allowed in the area of the mooring cells. The upper approach was excavated to el 785.0 along a line extending upstream from the land face of the landside lock wall to a point 215 ft landward of the lock center line at sta 46+00A. This provided a channel about 130 ft wide at the upstream end of the guard wall.

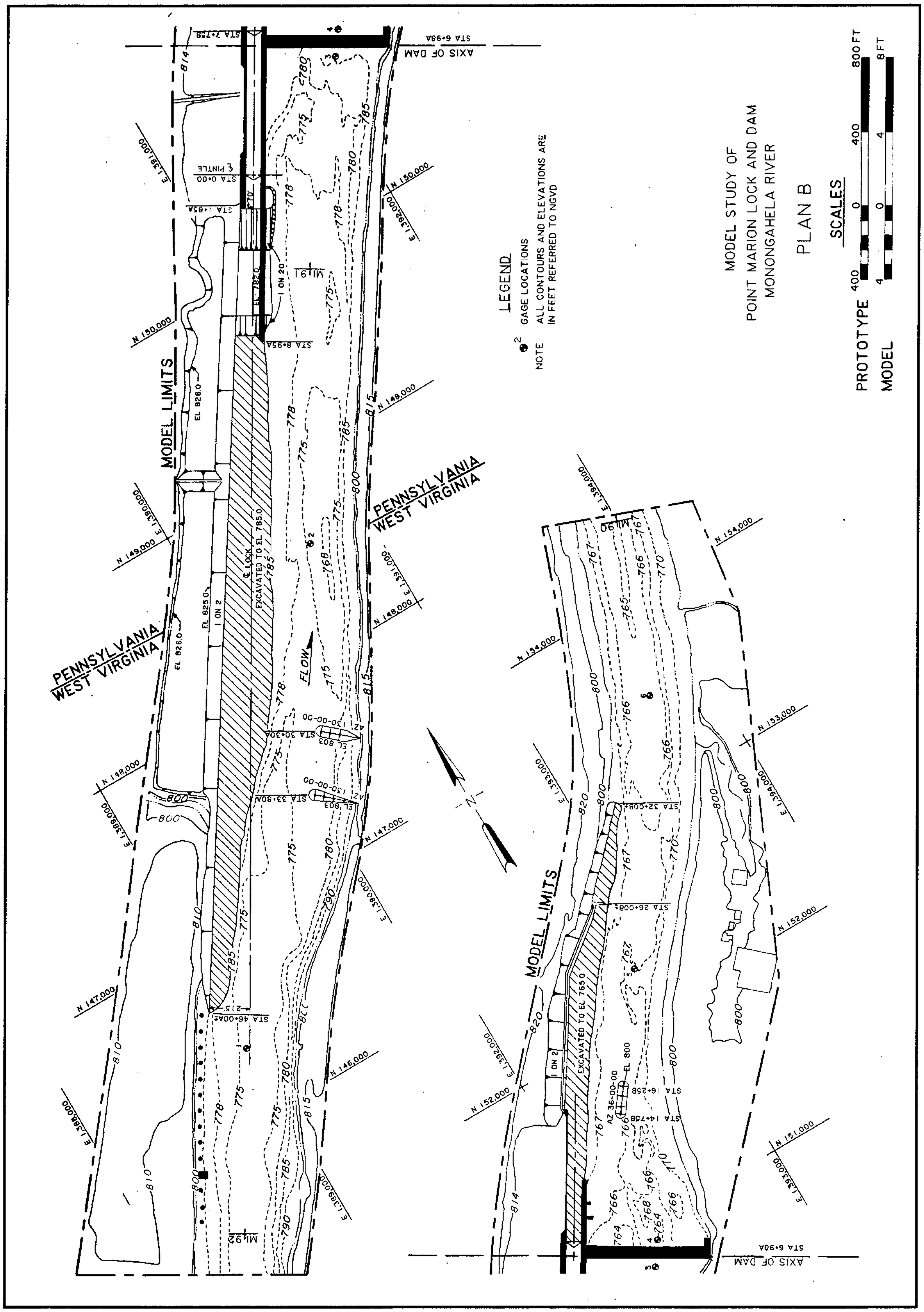


Figure 8. Plan B

b. Two spur dikes spaced about 350 ft apart with top el 803.0 were constructed along the right bank. The dikes were angled downstream slightly to reduce the magnitude of the current forces on the dikes. The river end of the first dike was located at sta 33+80A and 350 ft riverward of the lock center line and extended along azimuth 130 deg to tie into the right bank. The river end of the second dike was located at sta 30+30A and 380 ft riverward of the lock center line and extended along azimuth 130 deg to tie into the right bank.

c. A 150-ft-long vane dike with top el 800.0 was constructed downstream of the dam and riverward of the lower lock approach. The dike was designed during preliminary experiments to provide protection for tows entering and leaving the new lock. The upstream end of the vane dike was located at sta 14+75B, and the downstream end of the dike was located at sta 16+25B. The alignment of the dike was azimuth 36 deg, and the upstream end of the dike was located 250.0 ft riverward of the lock center line. The downstream end of the dike was 260.0 ft riverward of the lock center line.

d. The left bank immediately downstream of the lock was modified to remove the turning basin and provide a straight bank line approaching the guide wall.

Results

Water-surface elevations. Water-surface elevations obtained with Plan B conditions are shown in Table 4. These data indicate an increase in water-surface elevation at Gauge 1 ranging from 0.1 to 0.5 ft with the 22,500- and 133,000-cfs riverflows, respectively, when compared with the original design. This increase can be attributed to a combination of the new channel contours molded in the upper reach of the model and the two spur dikes placed along the right descending bank. When compared with Plan A (new channel contours in upper reach of the model), the increase in water-surface elevation ranged from 0.1 to 0.2 ft with the 33,000- and 55,000-cfs riverflows, respectively. This increase in water-surface elevation can be directly attributed to the spur dikes and change in left bank excavation. Water-surface elevation was not measured for riverflows higher than 55,000 cfs with Plan A conditions. Therefore, a direct relationship for the increase in water-surface elevation attributed to the spur dikes and changed excavation with the higher riverflows can be made. The drop across the structure and the water-surface elevation downstream of the dam were generally the same as with the original design. A slight increase of 0.1 ft was indicated at Gauge 4 with the 133,000-cfs riverflow. This increase could be attributed to the vane dike.

Current directions and velocities. Current direction and velocities obtained with Plan B are shown in Plates 6-8. Current patterns upstream of the dam are shown in Photos 9-11. These data indicate that the current generally

Table 4
Water-Surface Elevations, Plan B

Gauge No.	Water-Surface Elevations for Discharge in 1,000 cfs						
	22.5	33	55	66	92	104	133
1	797.3	798.4	801.4	802.9	806.2	807.6	810.8
2	797.2	798.2	801.1	802.5	805.8	807.1	810.3
3	797.0[1]	798.0	800.7	802.1	805.3	806.7	809.9
4	788.6	792.1	797.0	799.3	803.1	804.6	808.2
5	788.6	792.1	796.6	799.2	803.0	804.4	808.0
6	788.5[1]	792.0[1]	796.8[1]	799.1[1]	802.8[1]	804.3[1]	807.7[1]

[1] Controlled elevation.

followed the left bank from the upstream end of the model to the lock approach. The spur dikes reduced the cross-sectional area of the river channel near the upstream end of the left bank excavation and moved the current into the excavated channel. Large, clockwise, low-velocity eddies formed along the right bank upstream and downstream of the spur dikes. These eddies were a considerable distance away from the preferred alignment for a tow approaching or leaving the lock. The maximum velocities of the current in the navigation channel varied from about 3.0 to 5.8 fps near the upstream mooring area, 3.3 to 5.8 fps about 2,000 ft upstream of the guard wall, and 1.8 to 2.2 fps near the upstream end of the guard wall. This indicates an increase in velocities of 0.4 to 0.6 fps in the vicinity of the spur dikes. However, the largest change in the velocities of the current was along the left bank where spur dikes moved more flow into the excavated channel. The velocities of the current along the left bank increased as much as 1.5 to 2.5 fps. Current direction and velocities data shown in Plates 6 and 7 and current patterns shown in Photos 12 and 13 indicate that the vane dike downstream of the dam directed a considerable amount of flow into the lower lock approach and established downstream flow along the guide wall and left bank. However, the current was moving at a steep angle to the wall. The maximum velocities of the current near the downstream end of the guide wall varied from about 3.2 to 5.5 fps with the 22,500- and 55,000-cfs riverflows, respectively. The maximum velocities of the current in the navigation channel downstream of the lock varied from about 2.8 to 4.3 fps about 2,000 ft downstream of the dam and 2.8 to 4.5 fps about 4,000 ft downstream of the dam with the 22,500- and 55,000-cfs riverflows, respectively.

Navigation conditions. Navigation conditions for tows entering and leaving the upper lock approach were satisfactory for all flows up to the maximum navigable flow of 55,000 cfs (Photos 14-16). A downbound tow could enter the model reach from midchannel, drive into the excavated channel, align with the guard wall about three tow lengths upstream of the wall, start reducing speed, and enter the lock forebay at a safe speed with all riverflows through 55,000 cfs

(Photo 15). The tow could make a slow approach to the guard wall without any tendency for the tow to be moved out of the approach or for the head of the tow to move into the wall with excessive force. No difficulties were indicated for upbound tows leaving the lock. An upbound tow could move away from the guard wall and navigate upstream along the left bank (Photo 16) or move out into the main channel without any difficulties. Because the currents were moving across the lower lock approach, a downbound tow was required to rotate the head of the tow away from the guide wall about 15 deg before leaving the lower approach. After rotating the head of the tow off the guide wall, the tow could drive away from the lower approach and enter the main channel without any difficulties (Photos 17 and 18). Maneuvering the head of the tow away from the guide wall required additional time but was not a difficult maneuver. If the tow moved downstream without maneuvering the head of the tow off the wall, the clearance between the tow and the left bank was minimal for the tow to turn toward the main river channel, and the stern of the tow could ground on the left bank (Photo 19). Upbound tows could leave the main river channel and approach the lower guide wall without any major difficulties (Photos 20 and 21).

Plan B-Modified

Preliminary experiments

Preliminary experiments were conducted with the riverside lower lock wall shortened 185 ft to sta 9+35B. These experiments indicated that shortening the wall increased the flow entering the lower lock approach, creating a strong eddy near the entrance to the lock and creating strong crosscurrents near the downstream end of the landside guide wall. Downbound tows could not maneuver the head of the tow away from the guide wall and leave the lower approach without the possibility of the tow being grounded on the left bank. Upbound tows approaching the lock encountered strong currents near the downstream end of the guide wall, which tended to push the tow into the guide wall with considerable force. As the tow moved upstream along the wall to enter the lock chamber, the eddy that formed in the lower approach moved the head of the tow riverward and out of alignment with the chamber. An effort was made to correct the adverse conditions by relocating the 150-ft-long vane dike. Several locations were investigated without success. Adding a 100-ft-long vane dike near the downstream end of the riverside lock wall eliminated adverse conditions in the lower lock approach.

Description

Plan B-Modified (Figure 9) was the same as Plan B except for the following:

a. The riverside lower lock wall was shortened 185 ft to sta 9+35B due to changes in the lock design.

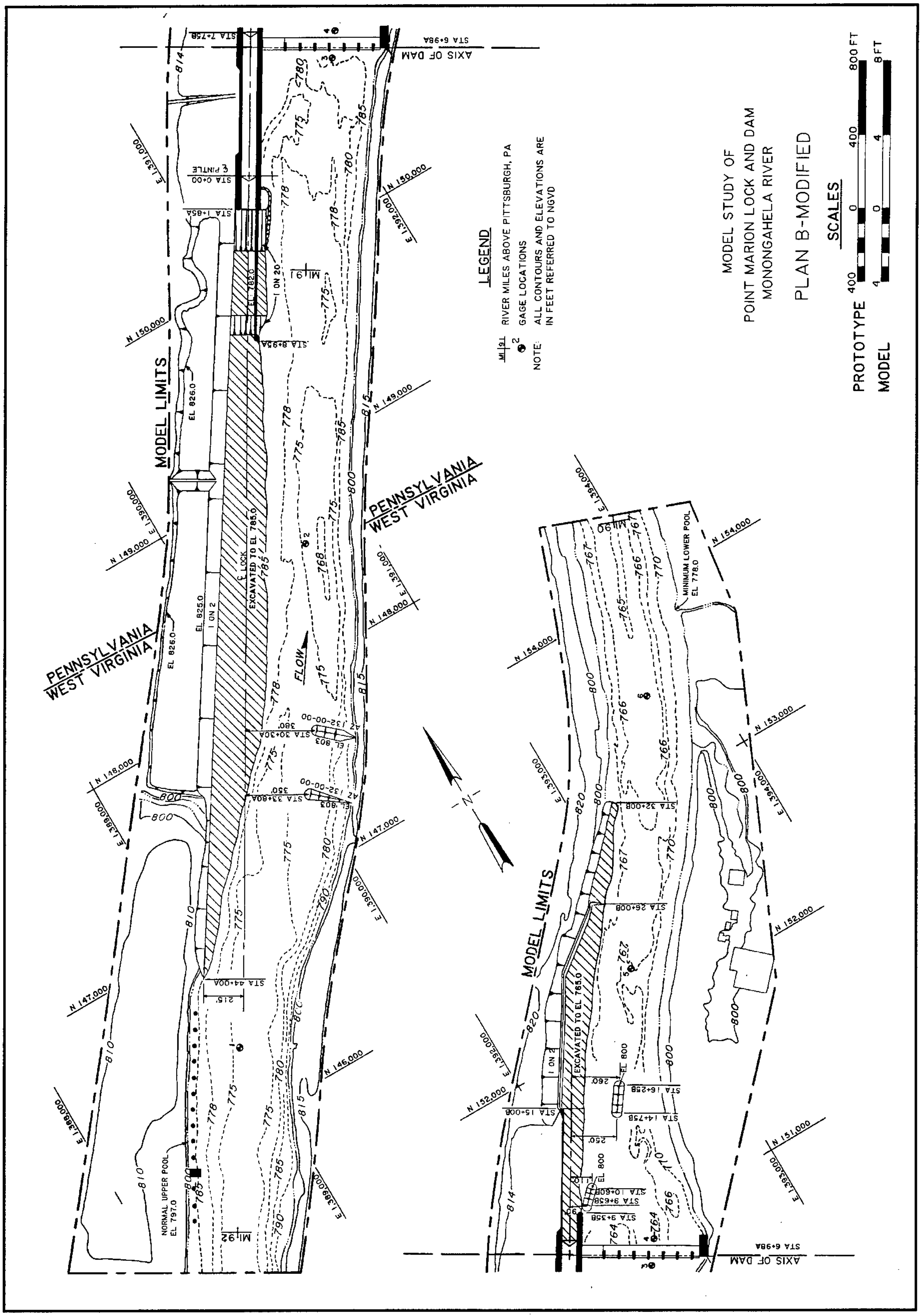


Figure 9. Plan B-Modified

b. A 100-ft-long vane dike with top el 800.0 was added at the downstream end of the riverside lock wall. The upstream end of the dike was located at sta 9+65B, and the downstream end of the dike was located at sta 10+60B. The dike was angled 15 deg riverward from parallel to the lock center line. The center line of the dike was placed to prevent the toe of the landside slope from encroaching on the entrance to the lock. The placement of the dike provided about a 50-ft opening between the upstream end of the dike and the downstream end of the lock wall. This allowed some flow to pass between the lock wall and the dike.

Results

Water-surface elevations. Water-surface elevations obtained with Plan B-Modified conditions are shown in Table 5. These data indicate that the water-surface elevations through the model reach were generally the same as with Plan B. However, with the 55,000-cfs riverflow, the water-surface elevation at Gauge 5 was 0.3 ft higher than Plan B. This can be attributed to a change in current patterns in the area.

Table 5
Water-Surface Elevations, Plan B-Modified

	Water-Surface Elevations for Discharge in 1,000 cfs		
Gauge No.	22.5	33	55
1	797.3	798.4	801.4
2	797.2	798.2	801.1
3	797.0[1]	798.0	800.7
4	788.6	792.1	797.0
5	788.6	792.0	796.9
6	788.5[1]	792.0	796.8[1]

[1] Controlled elevation.

Current directions and velocities. Current direction and velocity data shown in Plate 9 and current patterns shown in Photos 22 and 23 indicate that the flow through the spillway moved between the vane dike near the end of the riverside lock wall and the vane dike near midchannel and across the lower lock approach at a steep angle. Some flow passed through the opening between the vane dike and the downstream end of the riverside lock wall. However, a small counterclockwise eddy formed immediately downstream of the lock chamber (Plate 9). The velocity of the current in the eddy varied from less than 0.5 to about 1.7 fps with the 33,000- and 55,000-cfs riverflows, respectively. The maximum velocities of the current near the downstream end of the guide wall varied from about 3.4 to 4.0 fps with the 22,500- and 55,000-cfs riverflows,

respectively. The maximum velocities of the current in the navigation channel downstream of the lock varied from about 3.0 to 4.3 fps about 2,000 ft downstream of the dam and 3.2 to 4.3 fps about 4,000 ft downstream of the dam with the 22,500- and 55,000-cfs riverflows, respectively.

Navigation conditions. Navigation conditions for tows entering and leaving the lower lock approach were satisfactory with all flows. However, downbound tows were required to rotate the head of the tow away from the guide wall about 15 deg before leaving the lower approach. After rotating the head of the tow off the guide wall, the tow could drive away from the lower approach and enter the main channel without any difficulties (Photos 24 and 25). Maneuvering the head of the tow away from the guide wall would require additional time but was not a difficult maneuver. If the tow moved downstream without maneuvering the head of the tow off the wall, the clearance between the tow and the left bank was minimal for the tow to turn toward the main river channel (Photo 26). Upbound tows could leave the main river channel, align with the guide wall, and enter the lock chamber without any difficulties (Photos 27 and 28). There was no tendency for the head of the tow to move away from the guide wall as the tow entered the lock chamber.

Drawdown experiments. Experiments were conducted with the model reproducing drawdown conditions as defined by the Pittsburgh District. The experiments were conducted with the 22,500- and 55,000-cfs riverflows to determine any changes in navigation conditions or current patterns caused by the lower stages of a drawdown condition. Water-surface elevations in the lower pool were lowered to simulate drawdown conditions. The lower pool was drawn down to the tailwater rating curve supplied by the Pittsburgh District. Model Gauge 4 was drawn down to el 792.5 from 797.0 (4.5 ft) with the 55,000-cfs riverflow and to 785.5 from 788.5 (3.0 ft) with the 22,500-cfs riverflow. The lower water-surface level in the lower pool did not affect the water-surface elevation in the upper pool. Therefore, experiments were not conducted upstream of the dam. During the drawdown experiments, dye and confetti were used to define the current patterns downstream of the dam. Observations of these current patterns were then compared with photographs of Plan B-Modified normal pool current patterns. This comparision and current direction and velocity data shown in Plate 10 indicated there was a slight change in the current alignment in the lower lock approach with the 22,500- and 55,000-cfs riverflows. However, navigation experiments with the model tow indicated no significant change in navigation conditions for tows entering or leaving the lower lock approach. Water-surface elevations measured with drawdown conditions are shown in Table 6. These data indicate a signficant change in water-surface elevation due to the nature of the experiments. The drop through the dam varied from about 11.6 to 8.5 ft with the 22,500- and 55,000-cfs riverflows, respectively. The slope in water-surface elevation varied from about 0.1 to 0.4 ft per mile downstream of the dam with the 22,500- and 55,000-cfs riverflows, respectively.

Table 6
Water-Surface Elevations, Plan B-Modified Drawdown Condition

	Water-Surface Elevations for Discharge in 1,000 cfs		
Gauge No.	22.5	33	55
1	797.3	798.4	801.2
2	797.2	798.3	801.1
3	797.0[1]	798.0	800.7
4	785.4	787.6	792.2
5	785.4	787.5	791.9
6	785.3[1]	787.4	791.8[1]

[1] Controlled elevation.

Plan C

Description

Plan C (Figure 10) was the same as Plan B-Modified except the elevation of the left bank excavation upstream of the lock was changed to el 782.0 (3 ft deeper than Plan B-Modified). This also provided more depth and therefore larger port openings along the upstream end of the guard wall. The alignment of the left bank excavation was also changed to align with a corresponding elevation along the existing bank in the vicinity of the upstream mooring cells. This represented the maximum excavation allowed in the area of the mooring cells. The upper approach was excavated to el 782.0 along a line extending upstream from the land face of the landside lock wall to a point 220 ft landward of the lock center line at sta 45+50A. This provided a channel about 130 ft wide at the upstream end of the guard wall.

Results

Water-surface elevations. Water-surface elevations obtained with Plan C conditions are shown in Table 7. These data show that the water-surface elevations were generally the same as with Plan B or Plan B-Modified.

Current directions and velocities. Current direction and velocities obtained with Plan C are shown in Plate 11. These data indicate that the current direction and velocities were generally the same as with Plan B or Plan B-Modified. The current followed the left descending bank from the upstream limits of the model to the upper lock approach with some flow moving around the upstream end of the guard wall. With the 55,000-cfs riverflow, a

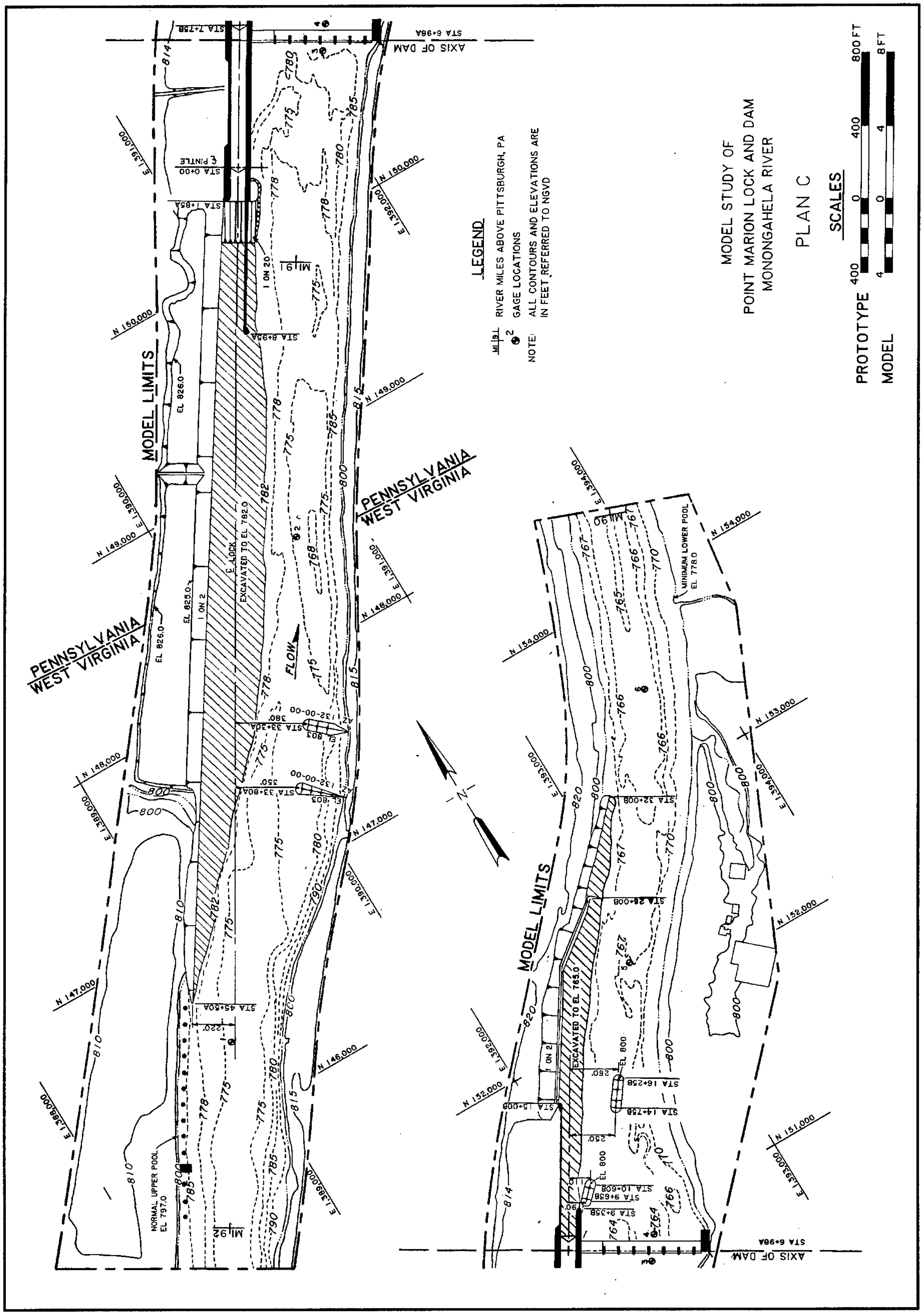


Figure 10. Plan C

Table 7 Water-Surface Elevations, Plan C			
	Water-Surface Elevations for Discharge in 1,000 cfs		
Gauge No.	22.5	33	55
1	797.3	798.4	801.4
2	797.2	798.2	801.1
3	797.0[1]	798.0	800.7
4	788.6	792.2	797.0
5	788.6	792.1	796.9
6	788.5[1]	792.0	796.8[1]

[1] Controlled elevation.

low-velocity counterclockwise eddy formed in the lock forebay near the entrance to the chamber. Current direction and velocity data shown in Plate 11 indicate that the flow was uniformly distributed along the guard wall. The maximum velocities of the current in the navigation channel varied from about 3.1 to 5.6 fps near the upstream mooring area, 3.1 to 6.3 fps about 1,500 ft upstream of the guard wall, and 1.8 to 3.5 fps near the upstream end of the guard wall. There was an increase in flow along the left bank and entering the lock forebay. However, there was no indication of an outdraft problem near the upstream end of the guard wall.

Navigation conditions. Navigation conditions were generally the same as with Plan B or Plan B-Modified. A downbound tow could enter the model reach from midchannel, drive into the excavated channel, align with the guard wall about three tow lengths upstream of the wall, start reducing speed, and enter the lock forebay at a safe speed with all riverflows through 55,000 cfs. The tow could make a slow approach to the guard wall without any tendency to be moved out of the approach or for the head of the tow to be moved into the wall with excessive force. No difficulties were indicated for upbound tows leaving the lock. An upbound tow could move away from the guard wall and navigate upstream along the left bank or move out into the main channel without any difficulties.

Drawdown experiments. Experiments were conducted with the model reproducing drawdown conditions as defined for Plan B-Modified. The experiments were conducted with the 22,500- and 55,000-cfs riverflows to determine any changes in navigation conditions or current patterns caused by the lower stages of a drawdown condition. During the drawdown experiments, dye and confetti were used to define the current patterns downstream of the dam. Observations of these current patterns were then compared with photographs of Plan C normal pool current patterns. This comparison indicated a slight change in the current alignment in the lower lock approach with the 22,500- and

55,000-cfs riverflows. However, navigation experiments with the model tow indicated no significant change in navigation conditions for tows entering or leaving the lower lock approach. Water-surface elevations measured with drawdown conditions are shown in Table 8. These data indicate a significant change in water-surface elevation due to the nature of the experiments. The drop through the dam varied from about 11.6 to 8.5 ft with the 22,500- and 55,000-cfs riverflows, respectively. The slope in water-surface elevation varied from about 0.1 to 0.4 ft per mile downstream of the dam with the 22,500- and 55,000-cfs riverflows, respectively.

Table 8
Water-Surface Elevations, Plan C, Drawdown Conditions

Gauge No.	Water-Surface Elevations for Discharge in 1,000 cfs		
	22.5	33	55
1	797.3	798.4	801.4
2	797.2	798.2	801.1
3	797.0[1]	798.0	800.7
4	785.4	787.6	792.2
5	785.4	787.5	791.9
6	785.3[1]	787.4	791.8[1]

[1] Controlled elevation.

Plan D

Description

The principal features of Plan D (Figure 11) were as follows:

a. The lock and dam structures were the same as Plan C except the ported upper guard wall was replaced with a 600-ft-long landside guide wall.

b. The left bank excavation was modified to provide a navigation channel to the landside guide wall. The upper approach channel was excavated to el 782.0 along a line extending upstream from the river face of the landside guide wall. The left bank was cut to a 1V on 2H slope with the toe of the slope 42 ft landward of the center line of the lock.

c. The two spur dikes along the right descending bank were removed

d. The area downstream of the dam was the same as Plan B-Modified.

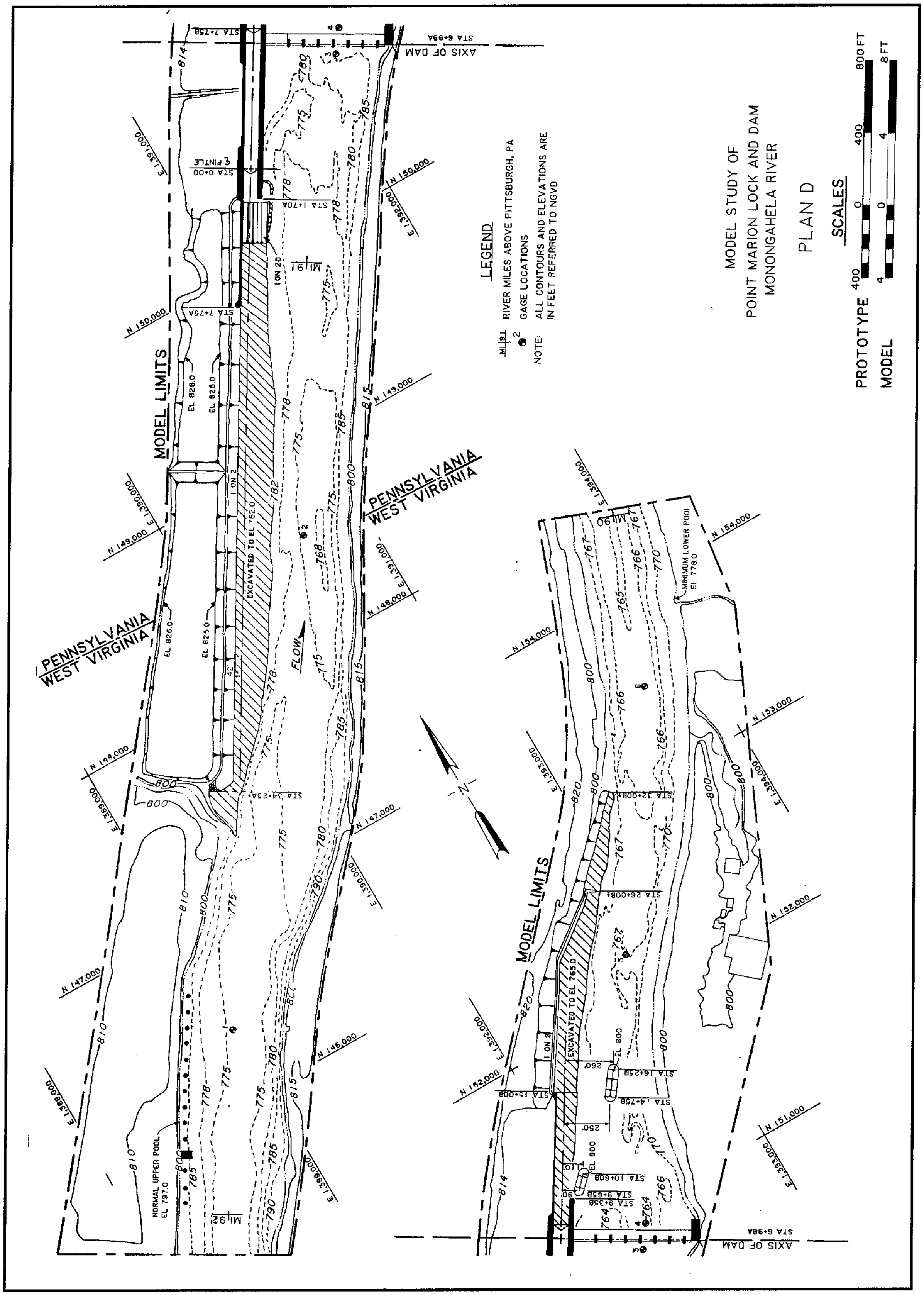


Figure 11. Plan D

Results

Water-surface elevations. Water-surface elevations obtained with Plan D conditions are shown in Table 9. These data show a decrease in water-surface elevations upstream of the dam compared with Plan C. This can be attributed to the removal of the spur dikes upstream of the dam. Water-surface elevations were generally the same as with Plan A.

Table 9
Water-Surface Elevations, Plan D

Gauge No.	Water-Surface Elevations for Discharge in 1,000 cfs		
	22.5	33	55
1	797.2	798.4	801.2
2	797.1	798.3	801.1
3	797.0[1]	798.0	800.7
4	788.6	792.2	797.0
5	788.6	792.1	796.9
6	788.5[1]	792.0	796.8[1]

[1] Controlled elevation.

Current directions and velocities. Current direction and velocities obtained with Plan D are shown in Plates 12-14. Confetti indicating surface current patterns are shown in Photos 29 and 30. These data indicate that the current generally followed the left descending bank from the upstream end of the model to about the upstream end of the lock guide wall. Then the current turned slightly riverward and moved across the upper lock approach toward the dam. The maximum velocities of the current in the navigation channel varied from about 3.3 to 6.3 fps near the upstream mooring area, 2.9 to 5.3 fps about 1,600 ft upstream of the guide wall, and 2.2 to 3.6 fps near the upstream end of the guide wall. Current directions and velocities measured downstream of the dam were generally the same as Plan B-Modified. Any changes in current patterns and velocities compared with Plan B-Modified can be attributed to floats being dropped at slightly different points and reacting slightly differently to the currents.

Navigation conditions. Navigation conditions for downbound tows were unsatisfactory with the 22,500-cfs riverflow and hazardous with the 55,000-cfs riverflow. With all flows up to the maximum navigable flow of 55,000 cfs, a downbound tow could enter the model reach at midchannel, drive to the left bank downstream of the mooring cells, and align with the guide wall three to four tow lengths upstream of the guide wall. With the 22,500-cfs riverflow, the tow was moved riverward of the lock approach as it reduced speed to enter the lock. The tow could drive the head of the tow to the guide wall, but some type of

assistance would be required for the tow to stay on the wall and align with the lock chamber (Photo 31). Maneuvering the head of the tow to the guide wall could require considerable time and maneuvering. As the riverflow increased to 55,000 cfs, the outdraft near the guide wall in the upper lock approach increased and created hazardous conditions for downbound tows. When a downbound tow reduced speed to approach the guide wall, it was moved riverward and out of alignment with the lock chamber (Photo 32). A downbound tow flanking to approach the guide wall was moved out of alignment with the guide wall as it approached the upstream end of the wall and could not maneuver to the wall (Photo 33). Upbound tows could leave the upper lock approach with no major difficulties with the 22,500-cfs riverflow (Photo 34). However, as the riverflow increased to 55,000 cfs, the currents moving across the lock approach could cause some minor difficulties. There was a slight tendency for the tow to be moved away from the guide wall before its stern cleared the lock chamber. This tendency could be overcome by the tow moving upstream close to the guide wall until the stern of the tow clears the lock chamber.

Drawdown experiments. Experiments were conducted with the model reproducing drawdown conditions as defined for Plan B-Modified. The experiments were conducted with the 22,500- and 55,000-cfs riverflows to determine any changes in navigation conditions or current patterns caused by the lower stages of a drawdown condition. During the drawdown experiments, dye and confetti were used to define the current patterns downstream of the dam. Observations of these current patterns were then compared with photographs of Plan D normal pool current patterns. This comparison indicated a slight change in the current alignment in the lower lock approach with the 22,500- and 55,000-cfs riverflows. However, navigation experiments with the model tow indicated no significant change in navigation conditions for tows entering or leaving the lower lock approach. Water-surface elevations measured with drawdown conditions are shown in Table 10. These data indicate a significant change in water-surface elevation due to the nature of the experiments. The drop through the dam varied from about 11.6 to 8.5 ft with the 22,500- and 55,000-cfs riverflows, respectively. The slope in water-surface elevation varied from about 0.1 to 0.4 ft per mile downstream of the dam with the 22,500- and 55,000-cfs riverflows, respectively.

Plan D-Modified

Description

Plan D-Modified (Figure 12) was the same as Plan D except a row of eight 20-ft-diam cells spaced 100 ft center to center extended upstream of the riverward lock wall. The center of the most downstream cell was located at sta 2+36A. The cells were parallel with the center line of the lock with their landside face located 95 ft riverward of the lock center line. A longitudinal dike was added riverward of the cells with the toe of the dike aligned with the

Table 10 Water-Surface Elevations, Plan D, Drawdown Conditions			
	Water-Surface Elevations for Discharge in 1,000 cfs		
Gauge No.	22.5	33	55
1	797.2	798.4	801.2
2	797.1	798.3	801.1
3	797.0[1]	798.0	800.7
4	785.4	787.6	792.2
5	785.4	787.5	791.9
6	785.3[1]	787.4	791.8[1]

[1] Controlled elevation.

landside face of the cells. The top of the dike was at el 805, and the side slopes were 1V on 1.5H. The upstream crest of the dike was at sta 9+36A, and the downstream end was at sta 2+36A. This provided a 66-ft-wide opening between the downstream crest of the dike and the riverside lock wall.

Results

Water-surface elevations. Water-surface elevations obtained with Plan D-Modified conditions are shown in Table 11. These data show the water-surface elevations were generally the same as Plan D.

Table 11 Water-Surface Elevations, Plan D-Modified			
	Water-Surface Elevations for Discharge in 1,000 cfs		
Gauge No.	22.5	33	55
1	797.2	798.4	801.2
2	797.1	798.3	801.1
3	797.0[1]	798.0	800.7
4	788.6	792.2	797.0
5	788.6	792.1	796.9
6	788.5[1]	792.0	796.8[1]

[1] Controlled elevation.

Current directions and velocities. Current direction and velocities obtained with Plan D-Modified are shown in Plate 15. Confetti showing surface current patterns are shown in Photos 35 and 36. The current generally followed the left bank from the upstream end of the model into the lock forebay. The

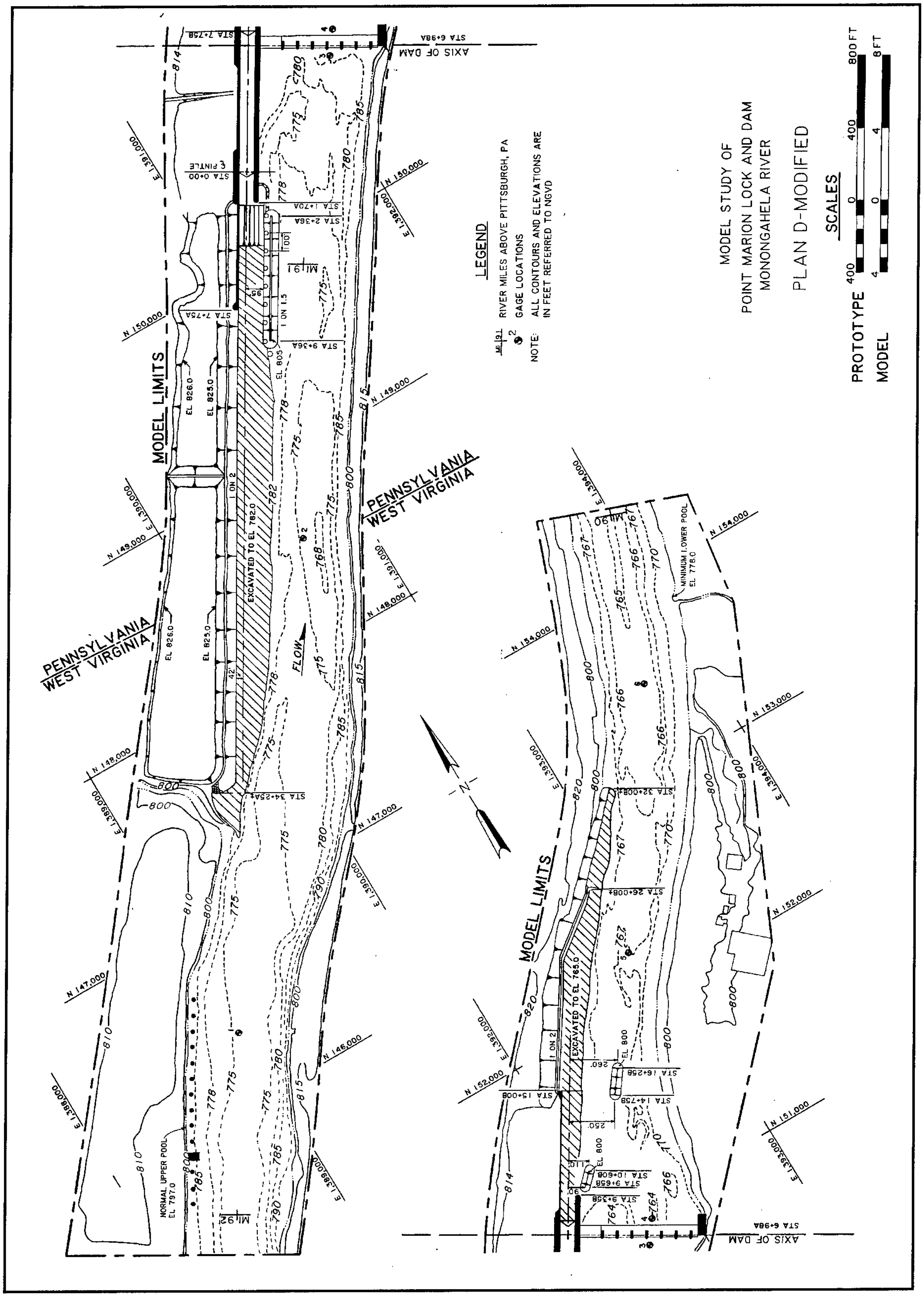


Figure 12. Plan D-Modified

opening between the downstream end of the longitudinal dike and the lock wall allowed current to enter the lock forebay, move along the dike parallel to the guide wall, and pass through the opening. This prevented any outdraft along the guide wall or large eddies forming in the lock forebay. The maximum velocities of the current in the navigation channel varied from about 3.3 to 5.6 fps near the upstream mooring area, 2.4 to 5.3 fps about 1,600 ft upstream of the guide wall, and 1.9 to 3.5 fps near the upstream end of the longitudinal dike with the 22,500- and 55,000-cfs riverflows, respectively.

Navigation conditions. The longitudinal dike reduced the outdraft along the upper guide wall observed in Plan D with all flows and allowed the tow to land on the guide wall about 300 ft downstream of its upstream end. The opening between the dike and the riverward lock wall allowed some flow to enter the lock approach and prevented an extreme outdraft from forming near the upstream end of the dike. A downbound tow could enter the model reach near midchannel, drive to the left bank downstream of the mooring cells, and align with the guide wall three to four tow lengths upstream of the guide wall. With the 22,500-cfs riverflow, a downbound tow could align with the guide wall, reduce speed, and land on the guide wall with no major difficulties (Photo 37). However, as the tow moved along the guide wall to enter the lock chamber, there was a tendency for the head of the tow to be moved away from the wall by the flow passing through the opening between the riverward lock wall and the dike. As the riverflow increased to 55,000 cfs, there was a tendency for the current to move the tow away from the guide wall and toward the cells as it entered the lock forebay. The tow could maneuver to the guide wall after entering the lock forebay (Photo 38). However, aligning with the guide wall and entering the lock chamber could require considerable maneuvering and time. As the tow moved along the guide wall and approached the lock chamber, there was a tendency for the head of the tow to be moved toward the opening between the lock wall and the longitudinal dike. Upbound tows could leave the upper lock approach with no major difficulties with all flows up to 55,000 cfs (Photos 39 and 40). There was no tendency for an upbound tow to be moved away from the guide wall as observed in Plan D. The cells and longitudinal dike would provide safe conditions for navigation into the lock forebay with no danger of tows striking the upper end of the dike. Tows properly aligned two to three tow lengths upstream of the dike would drift into the lock approach. With the higher flows, considerable time and maneuvering would be required for tows to align with and enter the lock.

Plan E

Description

The principal features of Plan E (Figure 13) were similar to Plan B upstream of the dam and Plan B-Modified downstream of the dam. The principal features of Plan E were as follows:

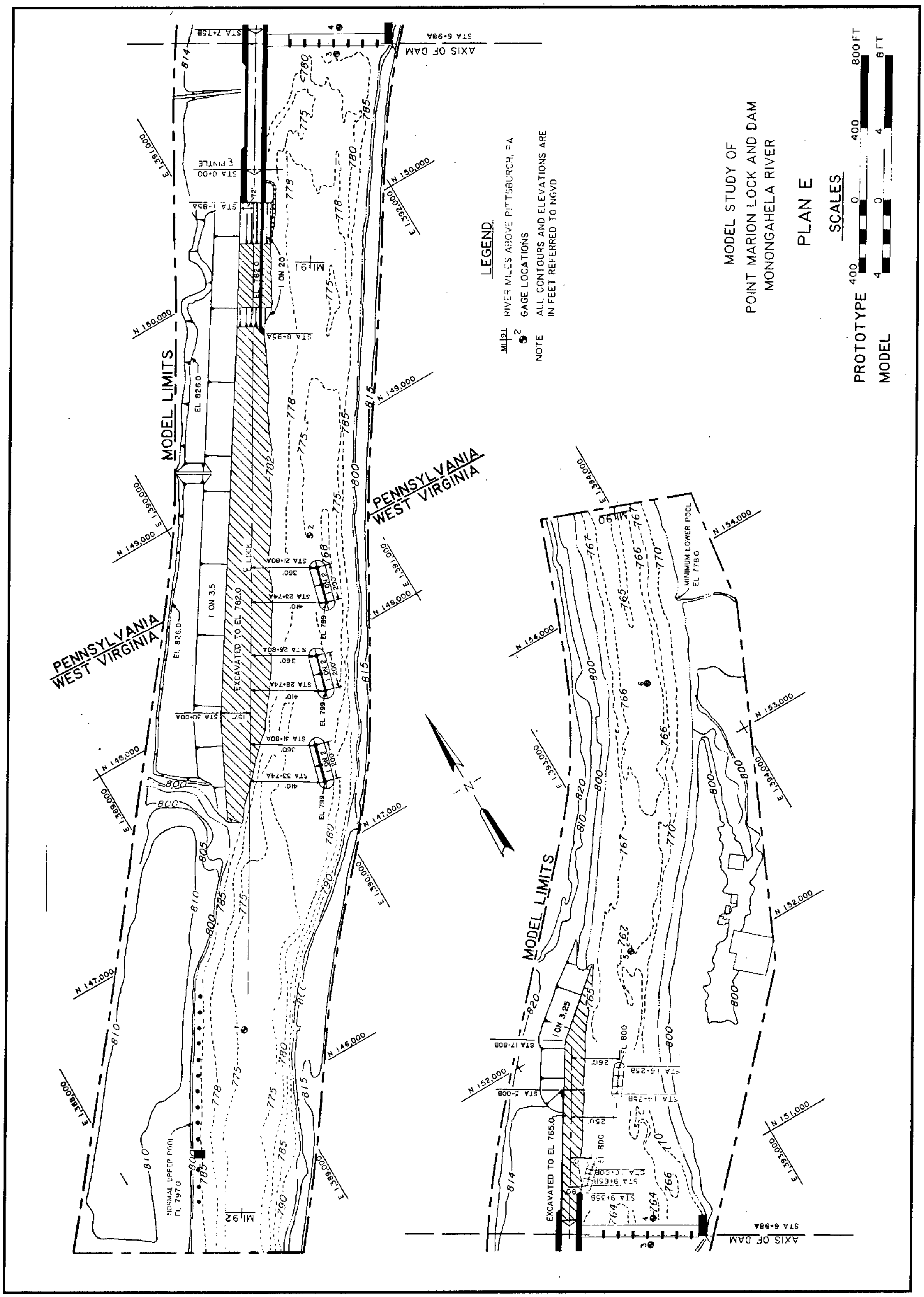


Figure 13. Plan E

a. A 490-ft nonnavigable gated spillway including six 70- by 8.5-ft tainter gates and seven 10-ft-wide piers. The dam was connected to the right bank by a 35-ft-long fixed-crest weir with a crest el of 795.7 and a 30-ft-long abutment with top el 805.0.

b. A new lock with clear chamber dimensions of 84 ft wide by 720 ft long constructed in the left bank adjacent to the existing lock. The top of the lock walls were at el 803.0. The new lock was 115 ft landward of and parallel to the first pier of the dam.

c. A 710-ft-long ported guard wall with seventeen 25-ft-diam cells spaced 40 ft on centers. This provides eighteen 15-ft-wide port openings with top of ports at el 792.0. The forebay of the lock was excavated to el 782.0. The top of the guard wall was el 803.0.

d. A 700-ft-long, solid lower guide wall extending downstream from the landside lock wall with top el 803.0. The effective length of the guide wall measured from the downstream end of the riverside lock wall was 565 ft.

e. Removal of the existing lock and replacement with a 110-ft-long fixed-crest overflow weir with crest at el 796.5 abutting the new lock and a 5-ft-long section with top el 805.0 abutting the first dam pier.

f. Excavation of the left bank to a 1V on 3.5H slope to el 782.0 along a line extending from the landside of the landward lock wall to a point 157 ft landward of the lock center line at sta 30+00A and then to a point 100 ft landward of the lock center line at sta 36+00A. This avoided any excavation upstream of Crooked Run Creek.

g. Adding three vane dikes upstream of the dam near the right bank at sta 21+80A, 26+80A, and 31+80A with crest el 799.0.

h. Excavation of the lower lock approach to el 765.0 extending downstream to sta 17+80 in line with the guide wall and then to a point 105 ft riverward of the lock center line at sta 22+00. This reproduced the minimum excavation requested by the Pittsburgh District. The left bank was excavated to a 1V on 3.25H slope.

i. Shortening of the riverside lower lock wall 185 ft to sta 9+35B due to changes in the lock design.

j. A 100-ft-long vane dike with top el 800.0 extending downstream from the downstream end of the riverside lock wall. The upstream end of the dike was located at sta 9+65B, and the downstream end of the dike was located at sta 10+60B. The dike was angled 15 deg riverward from parallel to the lock center line. The center line of the dike was placed so the toe of the landside slope would not encroach on the entrance to the

lock. The placement of the dike provided about a 30-ft opening between the upstream end of the dike and the downstream end of the lock wall. This allowed some flow to pass between the lock wall and the dike.

k. Construction of a 150-ft-long vane dike with top el 800.0 downstream of the dam and riverward of the lower lock approach. The upstream end of the vane dike was located at sta 14+75B, and the downstream end of the dike was located at sta 16+25B. The alignment of the dike was azimuth 36 deg, and the upstream end of the dike was located 250.0 ft riverward of the lock center line. The downstream end of the dike was 260.0 ft riverward of the lock center line.

Results

Water-surface elevations. Water-surface elevations obtained with Plan E conditions are shown in Table 12. These data indicate an increase in water-surface elevation at Gauge 1 ranging from 0.2 to 0.5 ft with the 22,500- and 133,000-cfs riverflows, respectively, when compared with the original design. This increase can be attributed to a combination of the new channel contours molded in the upper reach of the model and the three vane dikes placed along the right descending bank. When compared with Plan A (new channel contours in upper reach of the model), the increase in water-surface elevation ranged from 0.1 to 0.3 ft with the 33,000- and 55,000-cfs riverflows, respectively. This increase in water-surface elevation can be directly attributed to the vane dikes and change in left bank excavation. Water-surface elevation was not measured for riverflows higher than 55,000 cfs with Plan A conditions. Therefore, a direct relationship for the increase in water-surface elevation attributed to the vane dikes and changed excavation with the higher riverflows cannot be made. The drop across the structure and the water-surface elevation downstream of the dam were generally the same as with original design. A slight increase of 0.1 ft was indicated at Gauge 4 with the 133,000-cfs riverflow. This increase could be attributed to the vane dike.

Table 12
Water-Surface Elevations, Plan E

Gauge No.	Water- Surface Elevations for Discharge in 1,000 cfs						
	22.5	33	55	66	92	104	133
1	797.4	798.6	801.5	803.0	806.4	807.6	810.8
2	797.1	798.2	801.0	802.4	806.1	807.3	810.5
3	797.0[1]	798.0	800.7	802.1	805.3	806.7	809.9
4	788.6	792.2	797.1	799.3	803.2	804.7	808.1
5	788.6	792.1	796.9	799.2	802.9	804.4	807.8
6	788.5[1]	792.0[1]	796.8[1]	799.1[1]	802.8[1]	804.3[1]	807.7[1]

[1] Controlled elevation.

Current directions and velocities. Current direction and velocities obtained with Plan E are shown in Plates 16-18. Current patterns upstream of the dam are shown in Photos 41 and 42, and current patterns downstream of the dam are shown in Photos 43 and 44. These data indicate that the current generally followed the left bank from the upstream end of the model to the upstream end of the left bank excavation where the current tended to follow the main river channel. The vane dikes located near the right bank reduced the cross-sectional area of the river channel near the upstream end of the left bank excavation and moved the current into the excavated channel. The current was erratic in the vicinity of the vane dikes. However, this disturbance did not extend into the navigation channel approaching the lock. The maximum velocities of the current in the navigation channel varied from about 3.1 to 5.6 fps near the upstream mooring area, 3.3 to 6.1 fps about 1,500 ft upstream of the guard wall, and 2.2 to 3.7 fps near the upstream end of the guard wall. Current direction and velocity data shown in Plates 16-18 and current patterns shown in Photos 43 and 44 indicate the currents downstream of the dam were generally the same as with Plan B-Modified. These data indicate that the flow through the spillway moved between the vane dike near the end of the riverside lock wall and the vane dike near midchannel and across the lower lock approach at a steep angle. Some flow passed through the opening between the vane dike and the downstream end of the riverside lock wall. However, a small counter-clockwise eddy formed immediately downstream of the lock chamber with the 22,500- and 33,000-cfs riverflows. The velocity of the current in the eddy was generally less than 0.5 fps. The maximum velocities of the current near the downstream end of the guide wall varied from about 3.6 to 5.5 fps with the 22,500- and 55,000-cfs riverflows, respectively. The maximum velocities of the current in the navigation channel downstream of the lock varied from about 3.8 to 4.6 fps about 2,000 ft downstream of the dam and 3.6 to 4.2 fps about 4,000 ft downstream of the dam with the 22,500- and 55,000-cfs riverflows, respectively.

Navigation conditions. Navigation conditions were satisfactory for tows entering and leaving the upper lock approach with all riverflows up to the maximum navigable flow of 55,000 cfs (Photos 45-48). A downbound tow could enter the model reach from midchannel, drive into the excavated channel, align with the guard wall about two tow lengths upstream of the wall, start reducing speed, and enter the lock forebay at a safe speed with all riverflows through 55,000 cfs (Photos 45 and 46). The tow could make a slow approach to the guard wall without any tendency to be moved out of the approach or for the head of the tow to move into the wall with excess force. No difficulties were indicated for upbound tows leaving the lock. An upbound tow could move away from the guard wall and navigate upstream along the left bank or move out into the main channel without any difficulties (Photos 47 and 48). Although the design for the lower lock approach did not provide a full tow length of straight channel approaching the guide wall, navigation conditions for tows entering and leaving the lower lock approach were satisfactory with all flows. However, downbound tows were required to rotate the head of the tow away from the guide wall about 15 deg before leaving the lower approach. After rotating the head of the tow off the guide wall, the tow could drive away from the lower

approach and enter the main channel without any difficulties (Photos 49 and 50). Maneuvering the head of the tow away from the guide wall would require additional time but was not a difficult maneuver. If the tow moved downstream without maneuvering the head of the tow off the wall, the clearance between the tow and the left bank was minimal for the tow to turn toward the main river channel. Upbound tows could leave the main river channel, align with the guide wall, and enter the lock chamber without any difficulties (Photos 51 and 52). There was no tendency for the head of the tow to move away from the guide wall as the tow entered the lock chamber.

Meter velocities. Velocity measurements were made along the right descending bank in the vicinity of the proposed vane dikes to determine the potential for bank erosion. These measurements were made without and with the vane dikes in place (Plates 19 and 20, respectively) and the model reproducing the 92,000-cfs riverflow. These data indicate an increase in the velocity of the current in the vicinity of the vane dikes. Without the vane dikes, the velocity of the current along the right bank varied from 4.6 to 6.9 fps in the vicinity of the dike location. With the vane dikes in place, the velocity of the current along the right bank varied from 5.1 to 8.8 fps in the vicinity of the dikes. The highest velocities occurred near the land end of the vane dikes. Based on these measurements, some additional scouring of the bank could be expected in this area.

Drawdown experiments. Experiments were conducted with the model reproducing drawdown conditions as defined for Plan B-Modified. The experiments were conducted with the 22,500- and 55,000-cfs riverflows to determine any changes in navigation conditions or current patterns caused by the lower stages of a drawdown condition. During the drawdown experiments, dye and confetti were used to define the current patterns downstream of the dam. Observations of these current patterns were then compared with photographs of Plan E normal pool current patterns. This comparison indicated a slight change in the current alignment in the lower lock approach with the 22,500- and 55,000-cfs riverflows. Current direction and velocities measured with the 55,000-cfs riverflow are shown in Plate 21. These data indicate that the current pattern in the lower lock approach was generally the same as with normal tailwater conditions. However, lowering the tailwater increased the velocity of the currents. The maximum velocities of the currents with the 55,000-cfs riverflow varied from about 6.7 fps near the downstream end of the guide wall, to 6.3 fps about 2,000 ft downstream of the dam, and 6.3 fps about 4,000 ft downstream of the dam. However, navigation experiments with the model tow indicated no significant change in navigation conditions for tows leaving or entering the lower lock approach (Photos 53 and 54). Water-surface elevations measured with drawdown conditions are shown in Table 13. These data indicate a significant change in water-surface elevation due to the nature of the experiments. The drop through the dam varied from about 11.6 to 8.5 ft with the 22,500- and 55,000-cfs riverflows, respectively. The slope in water-surface elevation varied from about 0.1 to 0.4 ft per mile downstream of the dam with the 22,500- and 55,000-cfs riverflows, respectively.

Table 13 Water-Surface Elevations, Plan E, Drawdown Conditions			
	Water-Surface Elevations for Discharge in 1,000 cfs		
Gauge No.	22.5	33	55
1	797.4	798.6	801.5
2	797.1	798.2	801.0
3	797.0[1]	798.0	800.7
4	785.4	787.6	792.2
5	785.4	787.5	792.1
6	785.3[1]	787.4	791.8[1]

[1] Controlled elevation.

Recommendation. Navigation conditions could be improved for downbound tows by realigning the left bank excavation upstream of the lock to align with the left bank in the vicinity of the mooring cells similar to Plan B. This would provide more uniform currents entering the upstream end of the lock approach channel and allow tows to align with the guard wall farther upstream.

Plan E-Modified

Description

Plan E-Modified (Figures 14-16) is the same as Plan E except for the following:

a. The left bank slope, both upstream and downstream of the lock, was changed from 1V on 3.5H and 1V on 3.25H, respectively, to 1V on 3H.

b. The upper guard wall of the new lock was shortened 25 ft from sta 8+95A to sta 8+70A. The cell spacing remained the same as with Plan E. However, this eliminated one port opening. The new design of the guard wall provided seventeen 15-ft-wide port openings with top of ports at el 792.0 (Figure 15).

c. The limits of the excavation in the lower approach to the new lock were changed slightly to conform to more recent information.

d. The vane dike immediately downstream of the riverside wall of the new lock was replaced by leaving a portion of the existing lock in place and connecting it to the riverside wall of the new lock (Figure 16). This provided a wing wall to control flow moving into the lower lock approach. The downstream end of the wall was at sta 10+35B, and the

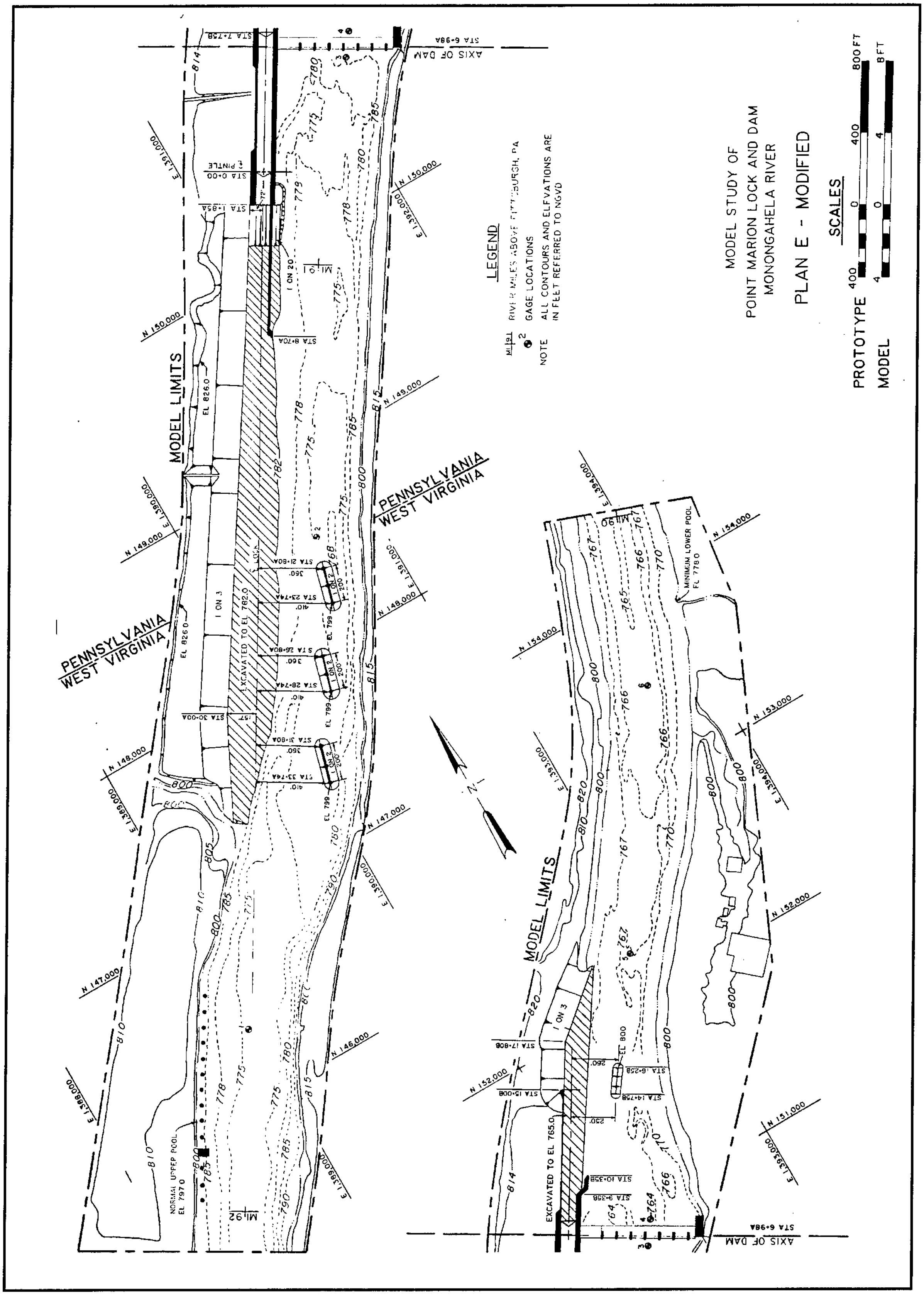


Figure 14. Plan E-Modified model layout

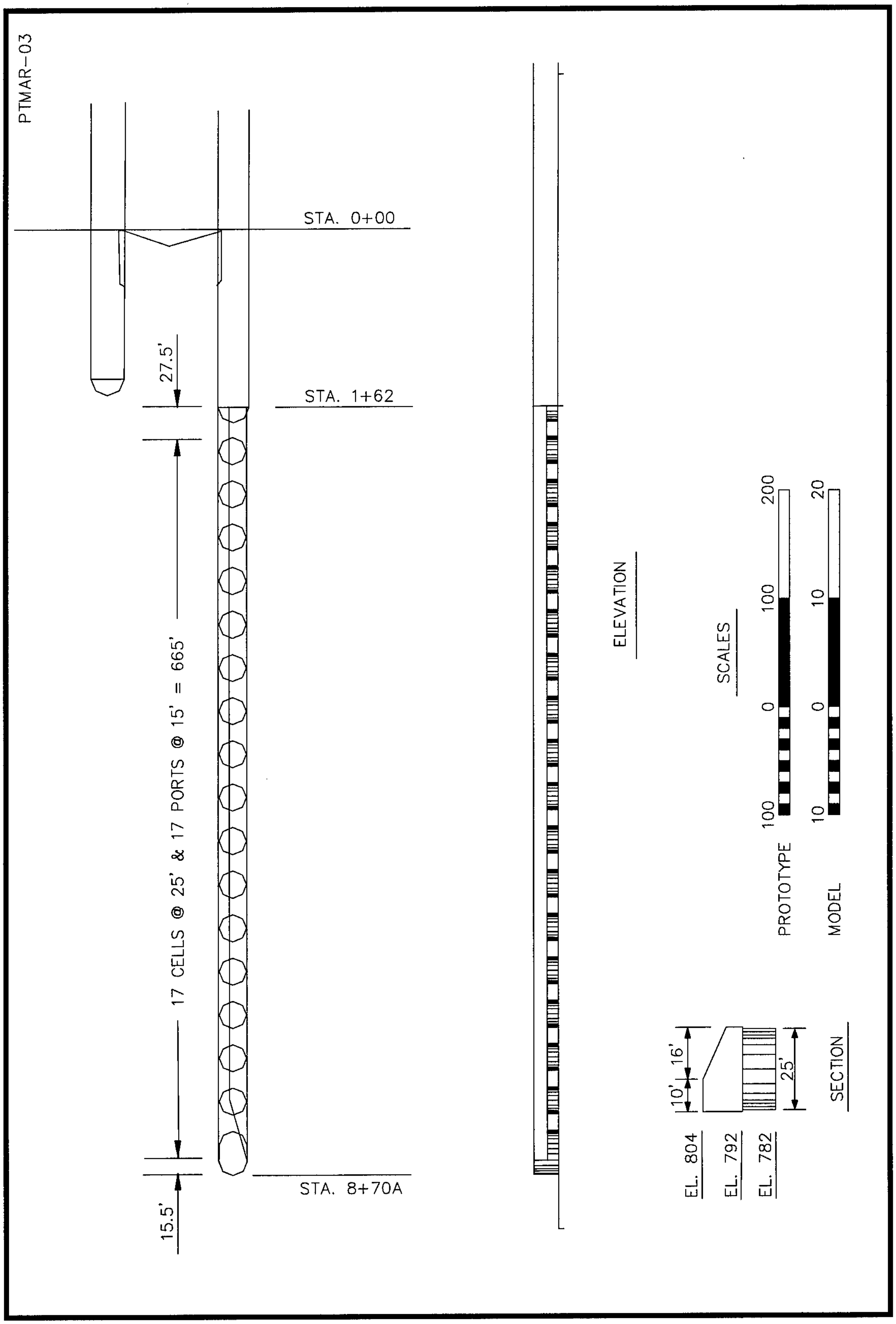


Figure 15. Plan E-Modified guard wall

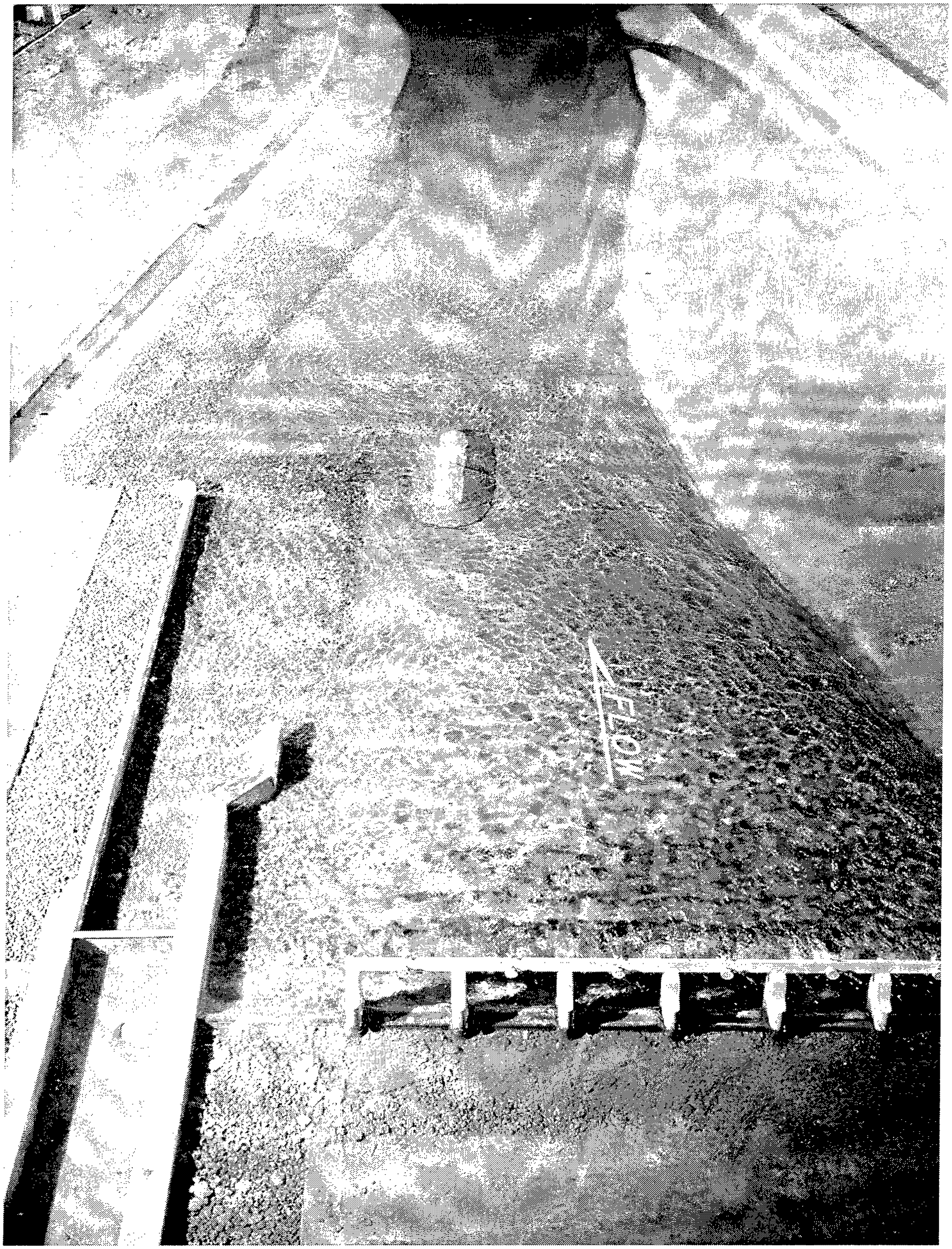


Figure 16. Vane dike

top of the wall was at el 803.0, the same as the top of the lock. The wall was parallel to and 50 ft riverward of the center line of the lock from its downstream end to sta 9+35B and then it angled into the downstream end of the riverside lock wall.

Results

Water-surface elevations. Water-surface elevations obtained with Plan E-Modified conditions are shown in Table 14. These data indicate that water-surface elevations were generally the same as with Plan E.

Table 14
Water-Surface Elevations, Plan E-Modified

Gauge No.	Water-Surface Elevations for Discharge in 1,000 cfs						
	22.5	33	55	66	92	104	133
1	797.4	798.6	801.5	803.0	806.4	807.6	810.8
2	797.1	798.2	801.0	802.4	806.1	807.3	810.5
3	797.0[1]	798.0	800.7	802.1	805.3	806.7	809.9
4	788.7	792.1	797.1	799.3	803.2	804.7	808.1
5	788.6	792.1	796.9	799.2	802.9	804.4	807.8
6	788.5[1]	792.0[1]	796.8[1]	799.1[1]	802.8[1]	804.3[1]	807.7[1]

[1] Controlled elevation.

Current directions and velocities. Current direction and velocities obtained with Plan E-Modified are shown in Plates 22-24. Confetti showing the current pattern downstream of the dam and in the vicinity of the lower lock approach is shown in Photos 55 and 56. These data indicate that the current pattern upstream and downstream of the dam was generally the same as with Plan E. The minor change of bank slope and 25-ft difference in length of the upper guard wall had no effect on the current directions or velocities in the upper pool. Any changes in direction or velocities of currents can be attributed to floats being dropped at slightly different locations and taking slightly different paths. Replacing the vane dike that extended downstream from the riverside wall of the lock with a solid angled wall had some influence on the currents in the vicinity of the lower lock approach. A small counterclockwise eddy formed in the lower lock approach between the solid wall and the landside guide wall. The velocity of the currents in the eddy were less than 0.5 fps. With the 22,500-cfs riverflow, a large counterclockwise eddy formed immediately downstream of the weir between the lock and the dam (Photo 55). As the riverflow increased, flow over the weir eliminated the eddy and established downstream flow along the lock wall and the wing wall (Photo 56).

Navigation conditions. Navigation conditions for tows entering and leaving the lock were generally the same as with Plan E. Navigation conditions were satisfactory for tows entering and leaving the upper lock approach with all riverflows up to the maximum navigable flow of 55,000 cfs. A downbound tow could enter the model reach from midchannel, drive into the excavated channel, align with the guard wall about two tow lengths upstream of the wall, start reducing speed, and enter the lock forebay at a safe speed with all riverflows through 55,000 cfs. The tow could make a slow approach to the guard wall without any tendency for the tow to be moved out of the approach or for the head of the tow to move into the wall with excessive force. Removing 25 ft of the upper guard wall did not adversely affect the performance of the wall. No difficulties were indicated for upbound tows leaving the lock. An upbound tow could move away from the guard wall and navigate upstream along the left bank or move out into the main channel without any difficulties. The solid wing wall performed similarly to the vane dike for tows entering and leaving the lower lock approach. Although an eddy formed between the wing wall and the landside guide wall, there was no indication that the eddy was strong enough to move the head of an upbound tow away from the landside guide wall and out of alignment with the lock chamber. Downbound tows were still required to rotate the head of the tow away from the guide wall about 15 deg before leaving the lower approach. After rotating the head of the tow off the guide wall, the tow could drive away from the lower approach and enter the main channel without any difficulties (Photos 57 and 58). Maneuvering the head of the tow away from the guide wall would require additional time but was not a difficult maneuver. If the tow moved downstream without maneuvering the head of the tow off the wall, the clearance between the tow and the left bank was minimal for the tow to turn toward the main river channel. Upbound tows could leave the main river channel, align with the guide wall, and enter the lock chamber without any difficulties (Photos 59 and 60).

Drawdown experiments. Experiments were conducted with the model reproducing drawdown conditions as defined for Plan B-Modified. The experiments were conducted with the 22,500- and 55,000-cfs riverflows to determine any changes in navigation conditions or current patterns caused by the lower stages of a drawdown condition. During the drawdown experiments, dye and confetti were used to define the current patterns downstream of the dam. Observations of these current patterns were then compared with photographs of Plan E-Modified normal tailwater current patterns. Confetti indicating the current pattern downstream of the dam with the 55,000-cfs riverflow is shown in Photo 61. Current direction and velocities measured with the 55,000-cfs riverflow are shown in Plate 25. These data indicate that the current pattern in the lower lock approach was generally the same as with normal tailwater conditions. However, lowering the tailwater increased the velocity of the currents. The maximum velocities of the currents with the 55,000-cfs riverflow varied from about 6.5 fps near the downstream end of the guide wall, to 6.6 fps about 2,000 ft downstream of the dam, and 6.0 fps about 4,000 ft downstream of the dam. Water-surface elevations shown in Table 15 indicate a significant change in water-surface elevation due to the nature of the experiments. The drop

Table 15
Water-Surface Elevations, Plan E-Modified, Drawdown Conditions

	Water-Surface Elevations for Discharge in 1,000 cfs		
Gauge No.	**22.5**	**33**	**55**
1	797.45	798.6	801.5
2	797.1	798.2	801.0
3	797.0[1]	798.0	800.7
4	785.5	787.7	792.3
5	785.4	787.5	792.1
6	785.3[1]	787.4	791.8[1]

[1] Controlled elevation.

through the dam varied from about 11.5 to 8.4 ft with the 22,500- and 55,000-cfs riverflows, respectively. The slope in water-surface elevation varied from about 0.2 to 0.5 ft per mile downstream of the dam with the 22,500- and 55,000-cfs riverflows, respectively. Navigation experiments with the model tow indicated no significant change in navigation conditions for tows entering and leaving the lower lock approach (Photos 62 and 63).

4 Results and Conclusions

Limitations of Model Results

Analysis of the results of this investigation is based on a study of (a) the effects of various plans and modifications on water-surface elevations and current directions and velocities and (b) the effects of the resulting currents on model towboat and tow behavior. An evaluation of experiment results should consider that small changes in current directions and velocities are not necessarily changes produced by a modification in the plan since several floats introduced at the same point may follow a different path and move at somewhat different velocities due to pulsating currents and eddies. Current directions and velocities shown in the plates were obtained with floats submerged to the depth of a loaded barge (9-ft prototype) and are more indicative of currents affecting the behavior of tows than those shown in photographs, which indicate the movement of confetti on the water surface and could be affected by surface tension.

The small scale of the model made it difficult to reproduce accurately the hydraulic characteristics of the prototype structures or to measure water-surface elevation with an accuracy greater than about ±0.1 ft prototype. Also, current directions and velocities were based on steady flows and would be somewhat different with varying flows. The model was a fixed-bed type and not designed to reproduce overall sediment movement that might occur in the prototype with the various plans. Therefore, changes in channel configuration resulting from scouring and deposition and any resulting changes in current directions and velocities were not evaluated.

Summary of Results and Conclusions

With the original design, navigation conditions were hazardous for downbound tows approaching the new lock with the 55,000-cfs riverflow. There was a tendency for a downbound tow leaving the lock to be moved into the left bank immediately downstream of the lock. Upbound tows approaching the lock were moved away from the guide wall by the eddy that formed in the lower approach of the lock.

The modified original design provided unsatisfactory navigation conditions for downbound tows approaching the lock with riverflows greater than 22,500 cfs.

Plan A provided unsatisfactory navigation conditions for downbound tows approaching the lock with the 55,000-cfs riverflow. Navigation conditions were improved for downbound tows approaching the lock with the 22,500- and 33,000-cfs riverflows. However, with the 55,000-cfs riverflows, downbound tows could not enter the lock approach at a safe speed.

Plan B provided satisfactory navigation conditions for tows entering and leaving the upper and lower lock approaches. However, downbound tows were required to rotate the head away from the guide wall before leaving the lower lock approach.

Plan B-Modified provided satisfactory navigation conditions for tows entering and leaving the lower lock approach with the new design for the riverside lock wall. However, downbound tows were required to rotate the head away from the guide wall before leaving the lower lock approach.

Plan C provided satisfactory navigation conditions for tows entering and leaving the upper lock approach.

Plan D did not provide satisfactory navigation conditions for downbound tows entering the upper lock approach.

Plan D-Modified provided safe navigation conditions for downbound tows entering the upper lock approach. However, considerable maneuvering was required for a downbound tow to align with and enter the lock chamber.

Plan E provided satisfactory navigation conditions for tows entering and leaving the upper and lower lock approaches with all riverflows. However, downbound tows were required to rotate the head away from the guide wall before leaving the lower lock approach.

Plan E-Modified provided satisfactory navigation conditions for tows entering and leaving the lower lock approach with the new design for the riverside lock wall. However, downbound tows were required to rotate the head away from the guide wall before leaving the lower lock approach.

Recommendations

Plan B-Modified will provide satisfactory navigation conditions for tows entering and leaving the lock with the proposed design for the new lock structure. However, navigation conditions could be improved for tows entering and leaving the lower lock approach by providing at least two tow lengths of

straight channel downstream of the guide wall. This would provide additional maneuvering area for upbound tows to align with the guide wall and allow downbound tows to drive away from the guide wall without rotating the head of the tow away from the wall.

Plan E or Plan E-Modified will provide satisfactory navigation conditions for tows entering and leaving the lock with the proposed design for the new lock structure. However, navigation conditions could be improved for downbound tows entering the upper lock approach by realigning the left bank excavation upstream of the lock to align with the left bank in the vicinity of the mooring cells similar to Plan B-Modified. Navigation conditions could also be improved for tows entering and leaving the lower lock approach by providing at least two tow lengths of straight channel downstream of the guide wall.

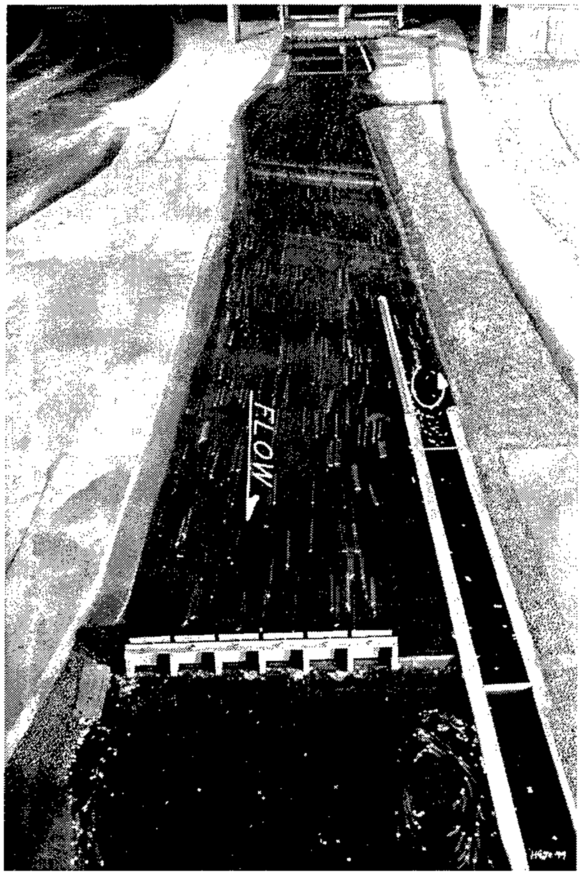
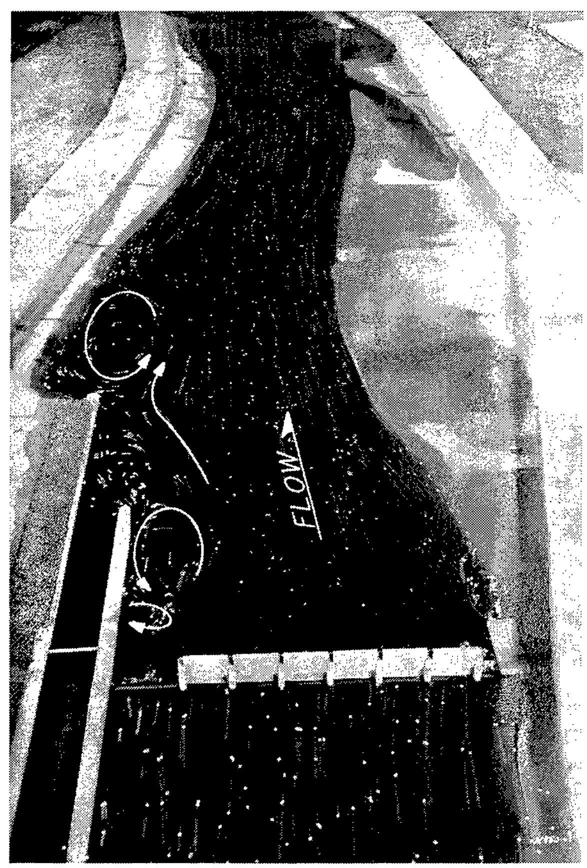


Photo 1. Original design, looking upstream, discharge 55,000 cfs, confetti showing surface current pattern in the upper approach to the lock

Photo 2. Original design, looking downstream, discharge 55,000 cfs, confetti showing surface current pattern in the lower approach to the lock



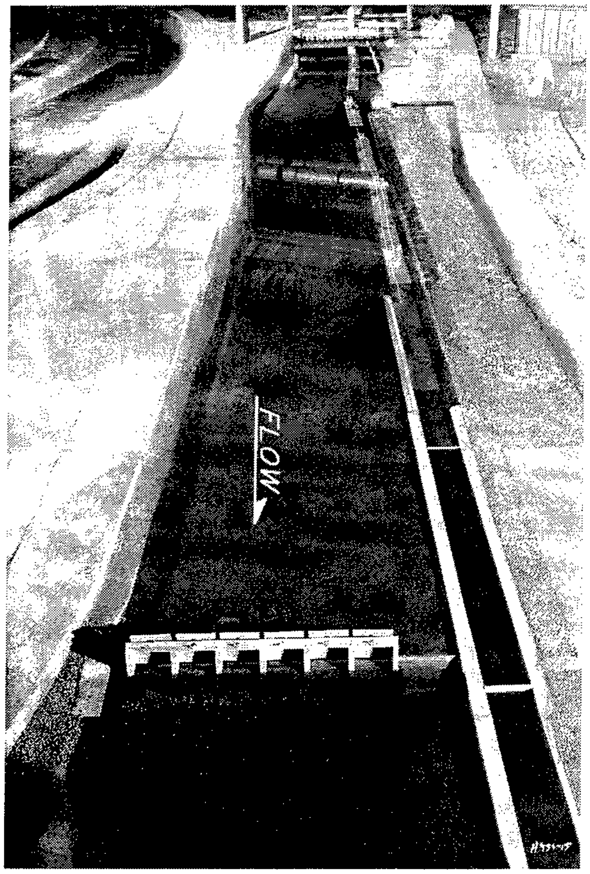


Photo 3. Original design, looking upstream, discharge 55,000 cfs, showing path of downbound tow approaching lock along left bank and entering lock approach

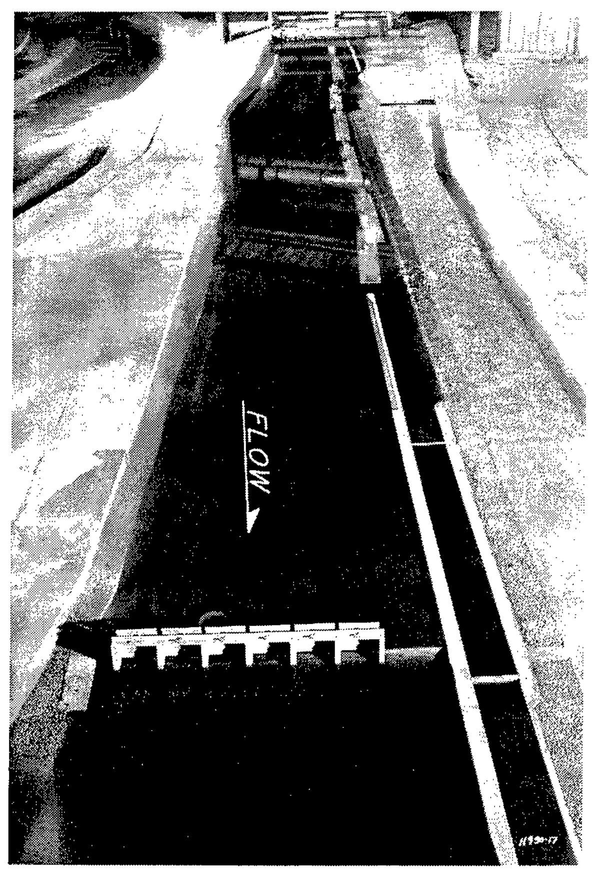


Photo 4. Original design, looking upstream, discharge 55,000 cfs, showing path of downbound tow approaching lock along left bank and being moved riverward of upper guard wall

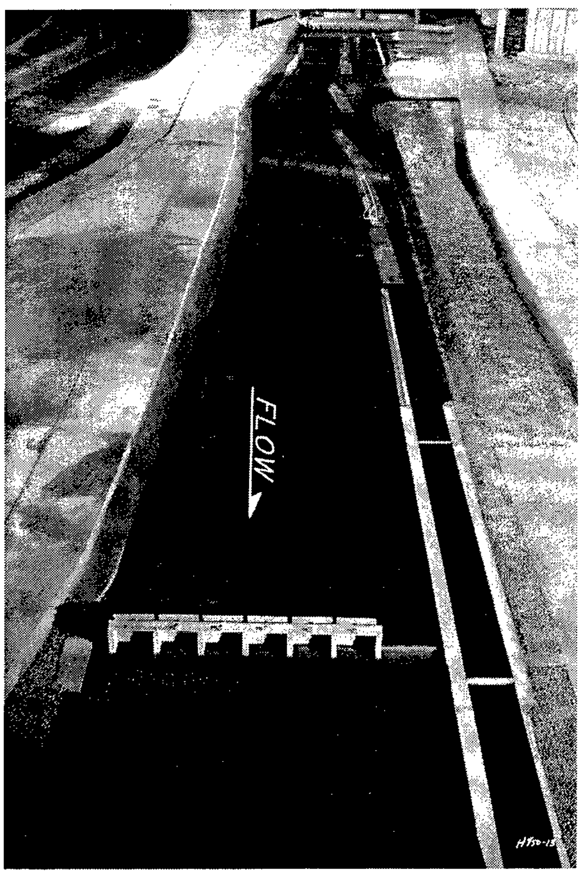


Photo 5. Original design, looking upstream, discharge 55,000 cfs, showing path of tow approaching lock from midchannel

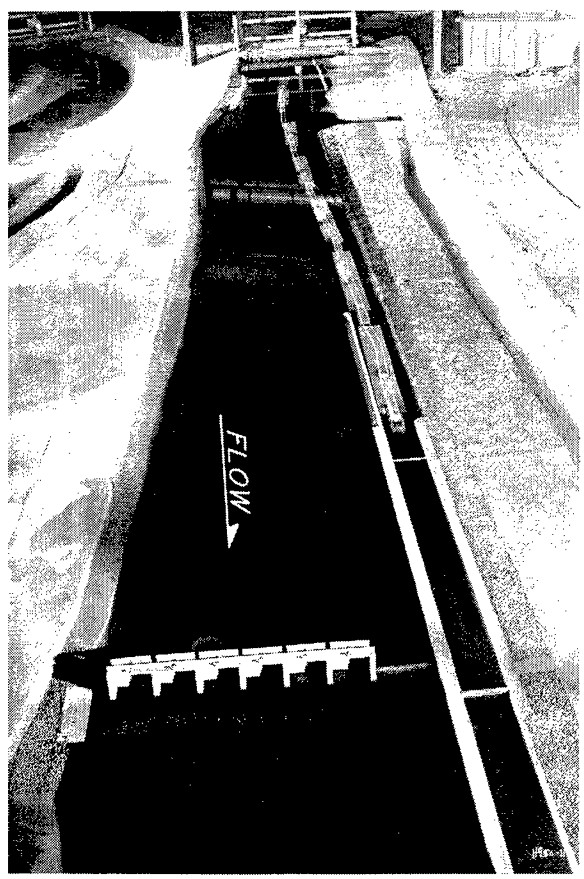


Photo 6. Original design, looking upstream, discharge 55,000 cfs, showing path of upbound tow leaving lock

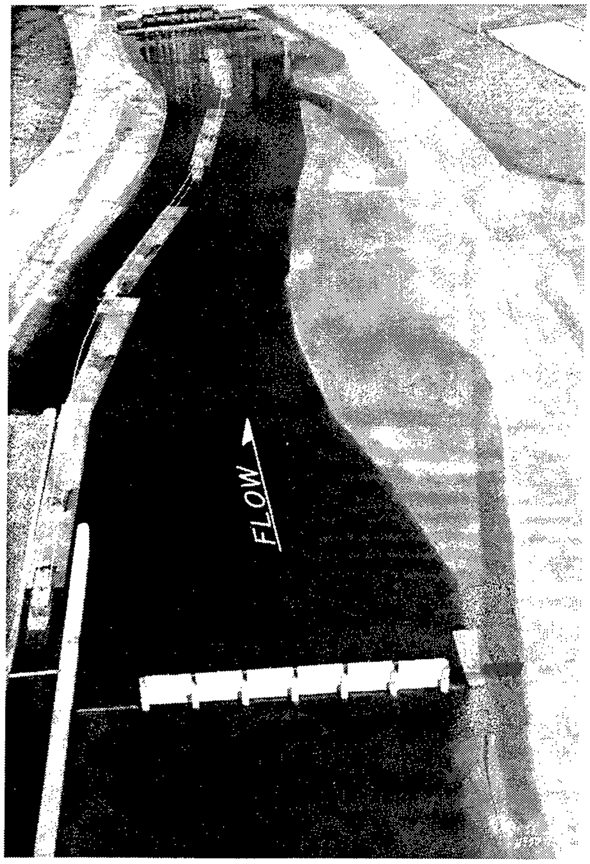


Photo 7. Original design, looking downstream, discharge 55,000 cfs, showing path of downbound tow leaving lock

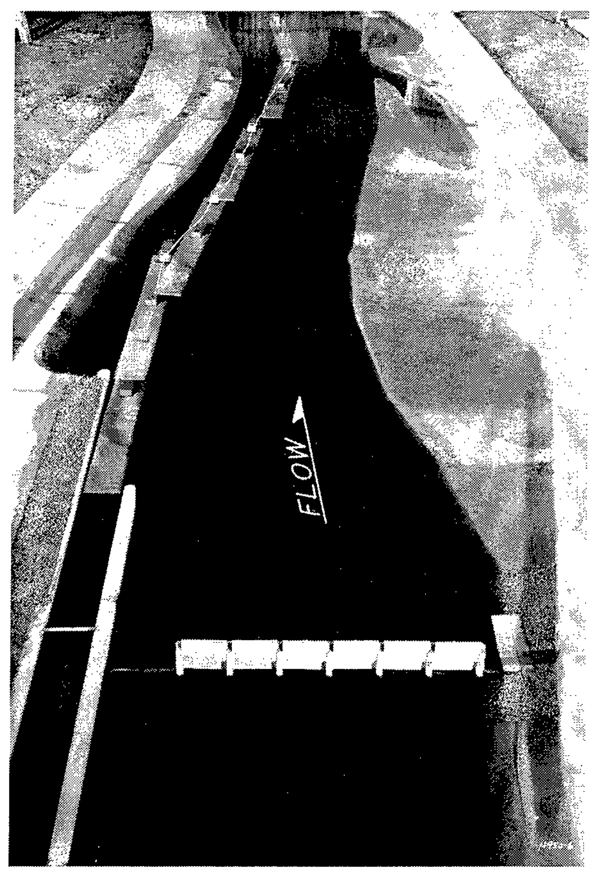


Photo 8. Original design, looking downstream, discharge 55,000 cfs, showing path of upbound tow approaching lock

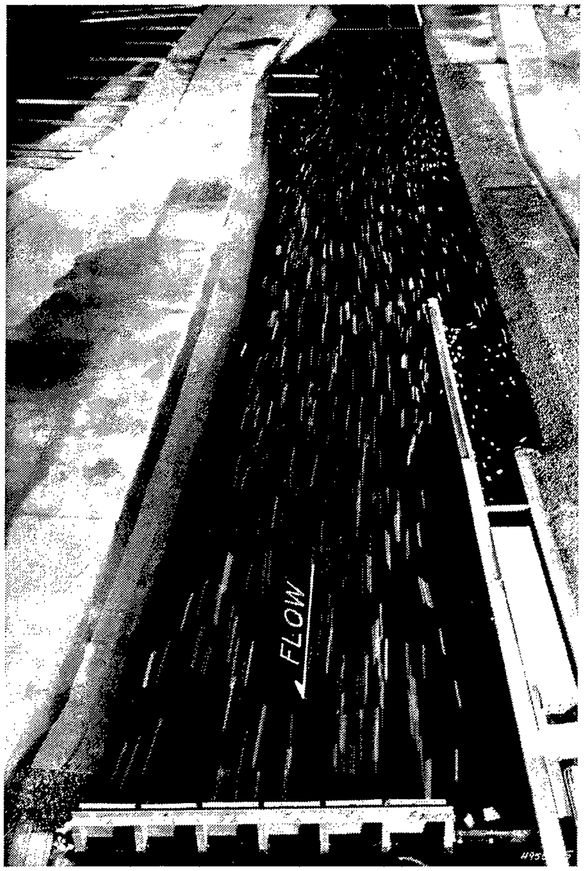


Photo 9. Plan B, looking upstream, discharge 22,500 cfs, confetti showing surface current patterns in the upper approach to the lock

Photo 10. Plan B, looking upstream, discharge 33,000 cfs, confetti showing surface current patterns in the upper approach to the lock

Photo 11. Plan B, looking upstream, discharge 55,000 cfs, confetti showing surface current patterns in the upper approach to the lock

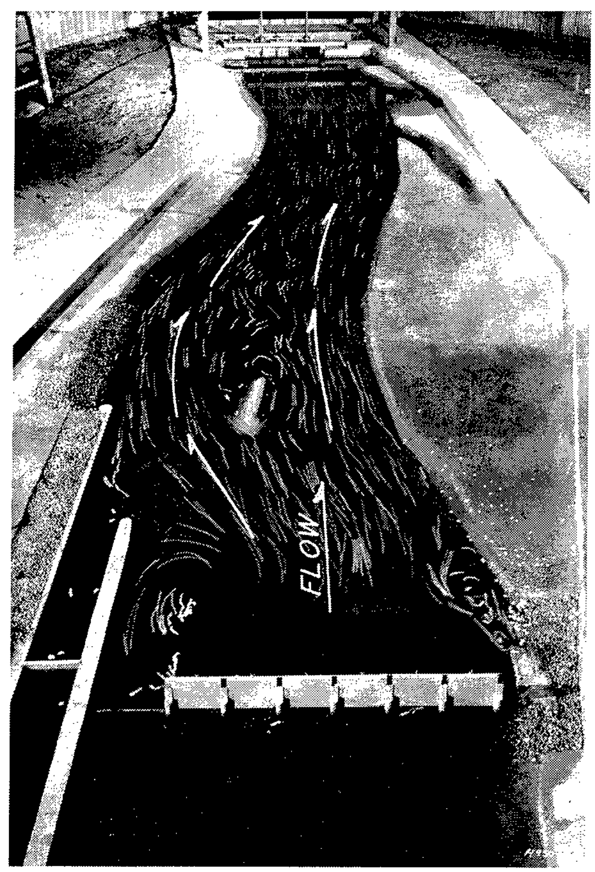


Photo 12. Plan B, looking downstream, discharge 22,500 cfs, confetti showing surface current pattern in the lower lock approach

Photo 13. Plan B, looking downstream, discharge 33,000 cfs, confetti showing surface current pattern in the lower lock approach

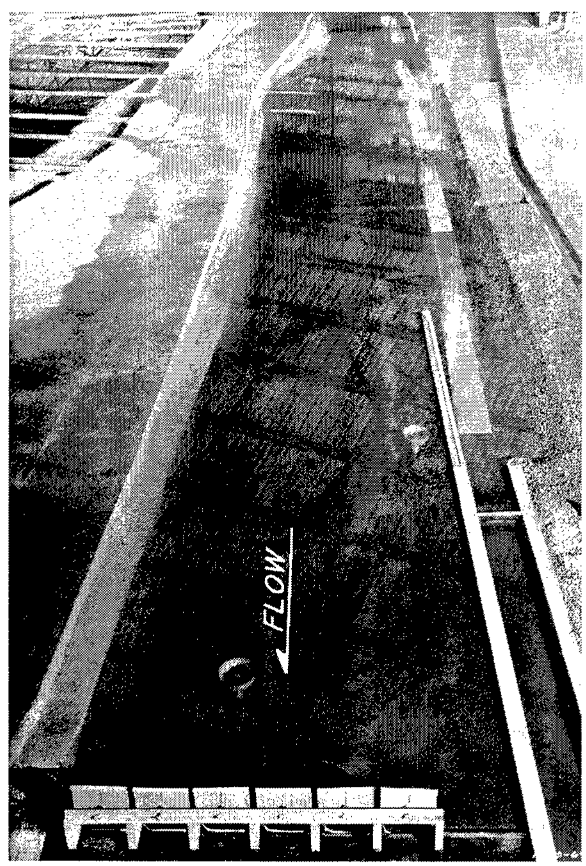


Photo 14. Plan B, looking upstream, discharge 55,000 cfs, showing path of downbound tow approaching lock along left bank

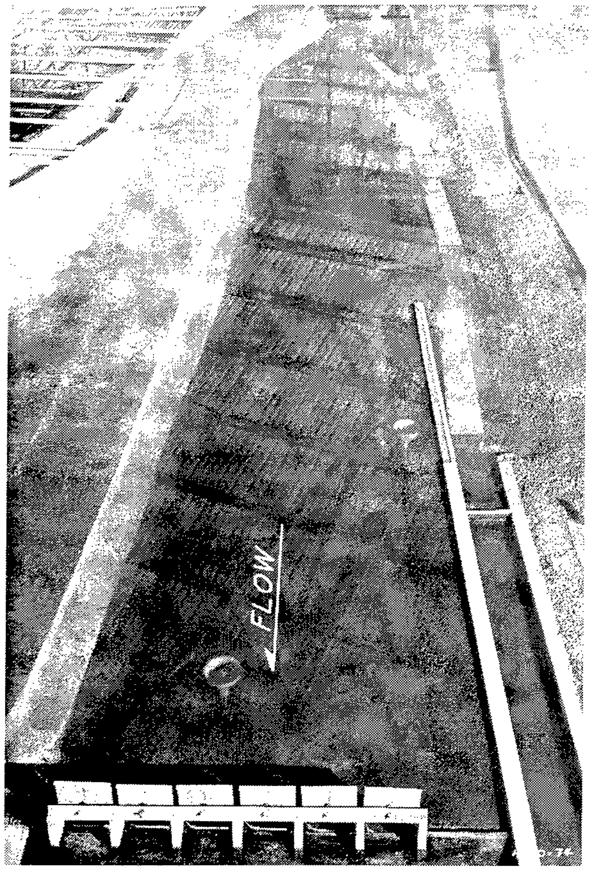


Photo 15. Plan B, looking upstream, discharge 55,000 cfs, showing path of downbound tow approaching lock from midchannel

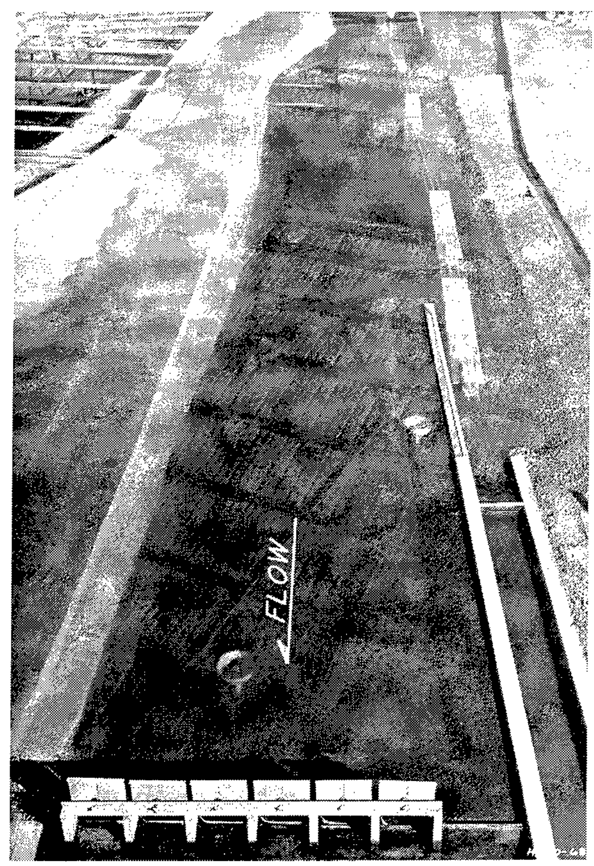


Photo 16. Plan B, looking upstream, discharge 55,000 cfs, showing path of upbound tow leaving lock

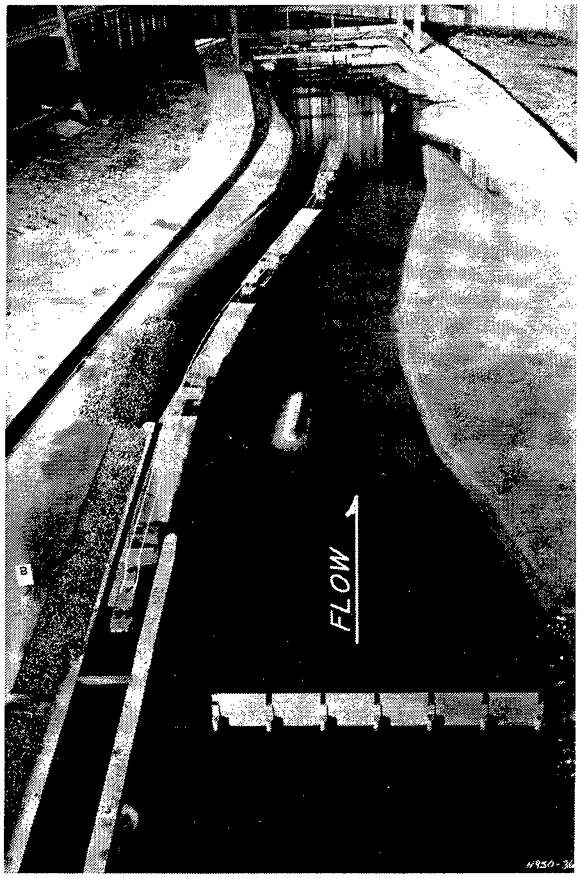


Photo 17. Plan B, looking downstream, discharge 22,500 cfs, showing path of downbound tow leaving lock near midchannel

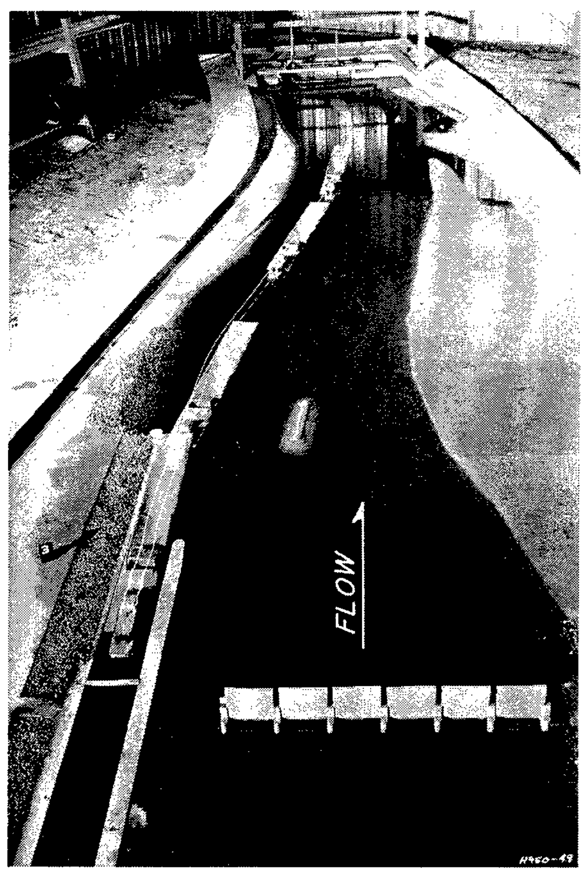


Photo 18. Plan B, looking downstream, discharge 55,000 cfs, showing path of downbound tow leaving lock

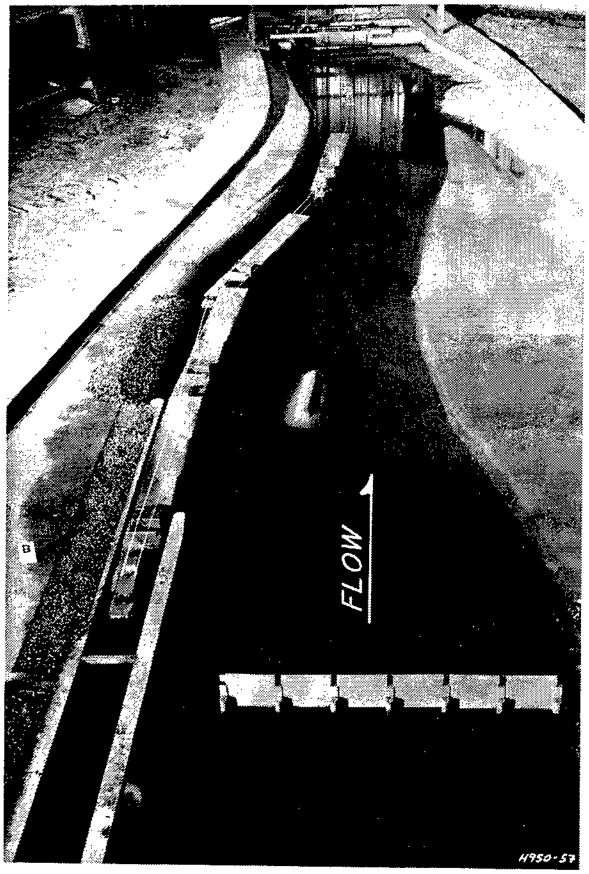


Photo 19. Plan B, looking downstream, discharge 22,500 cfs, showing path of downbound tow leaving lock along left bank

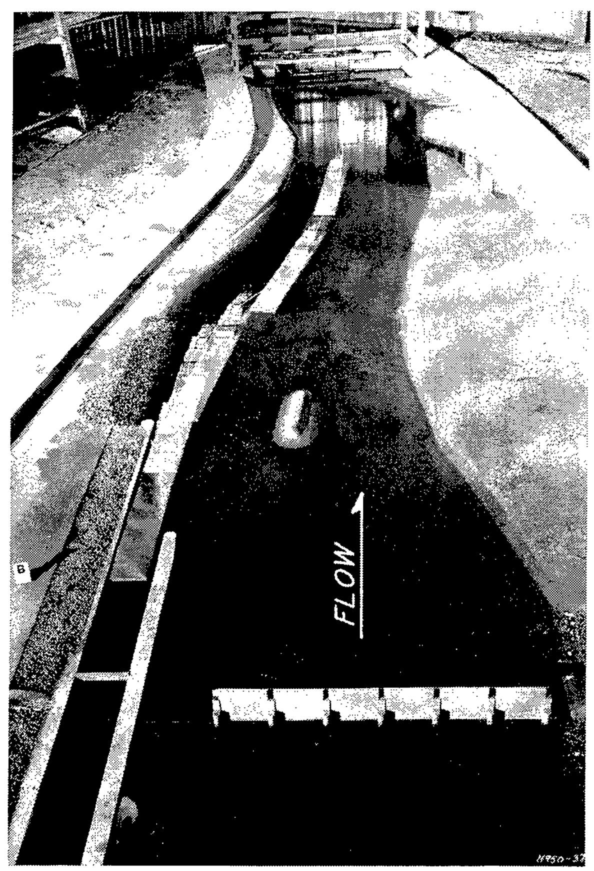


Photo 20. Plan B, looking downstream, discharge 22,500 cfs, showing path of upbound tow approaching lock

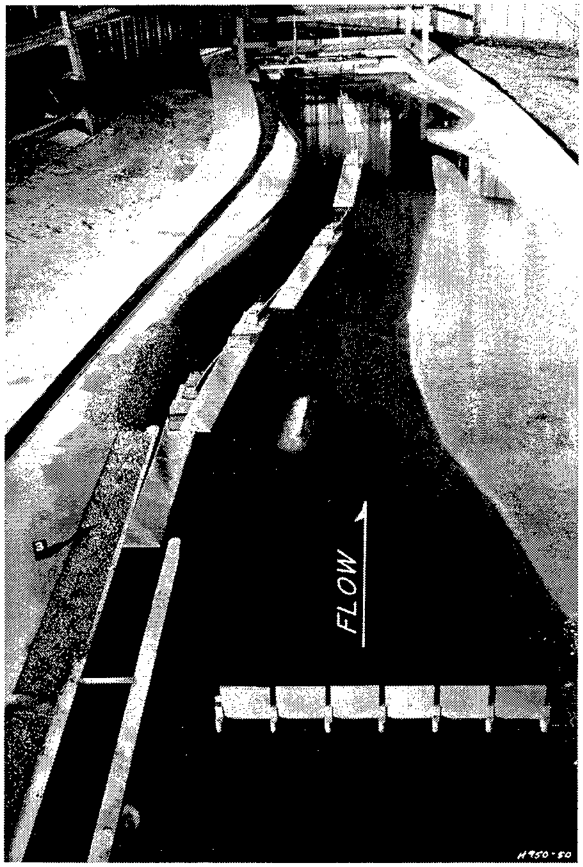
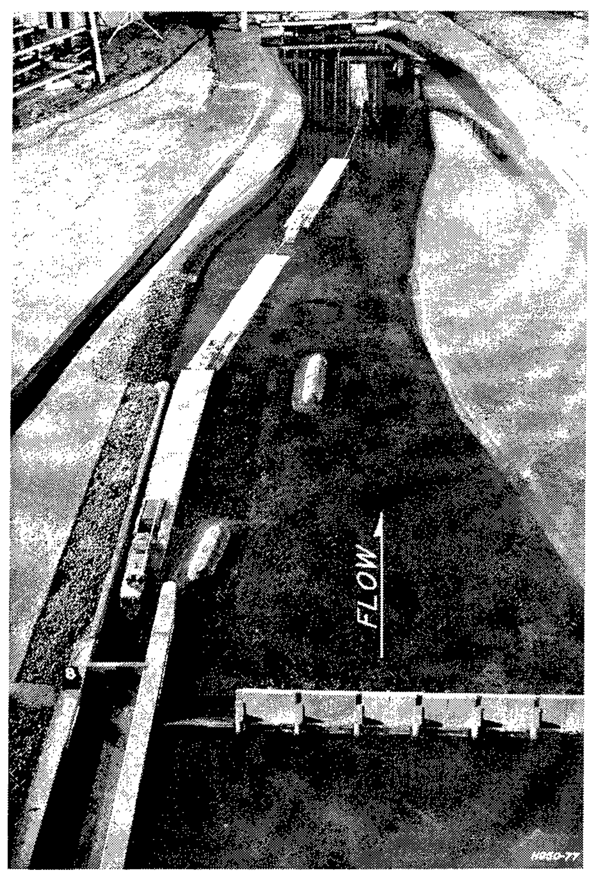


Photo 21. Plan B, looking downstream, discharge 55,000 cfs, showing path of upbound tow approaching lock from midchannel

Photo 22. Plan B-Modified, looking downstream, discharge 22,500 cfs, confetti showing surface current patterns in the lower approach to the lock

Photo 23. Plan B-Modified, looking downstream, discharge 55,000 cfs, confetti showing surface current patterns in the lower approach to the lock

Photo 24. Plan B-Modified, looking downstream, discharge 22,500 cfs, showing path of downbound tow leaving lock



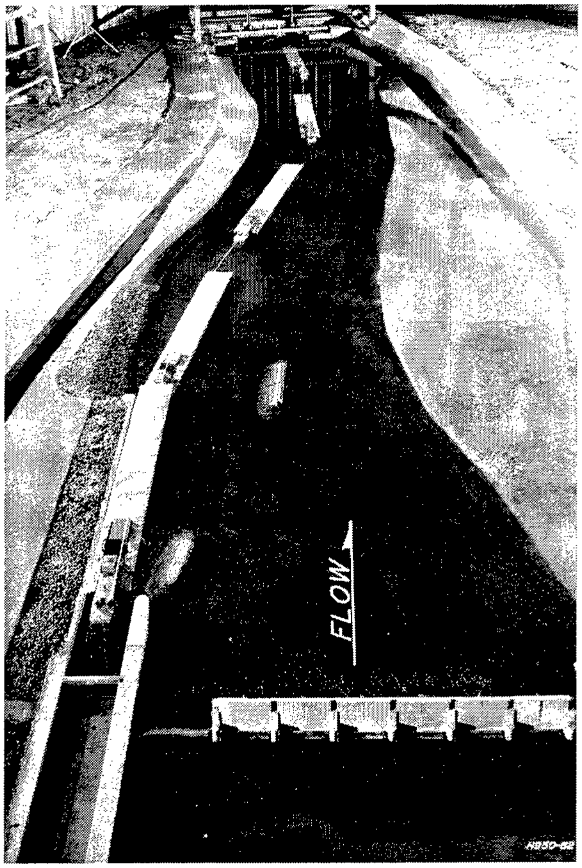


Photo 25. Plan B-Modified, looking downstream, discharge 55,000 cfs, showing path of downbound tow leaving lock

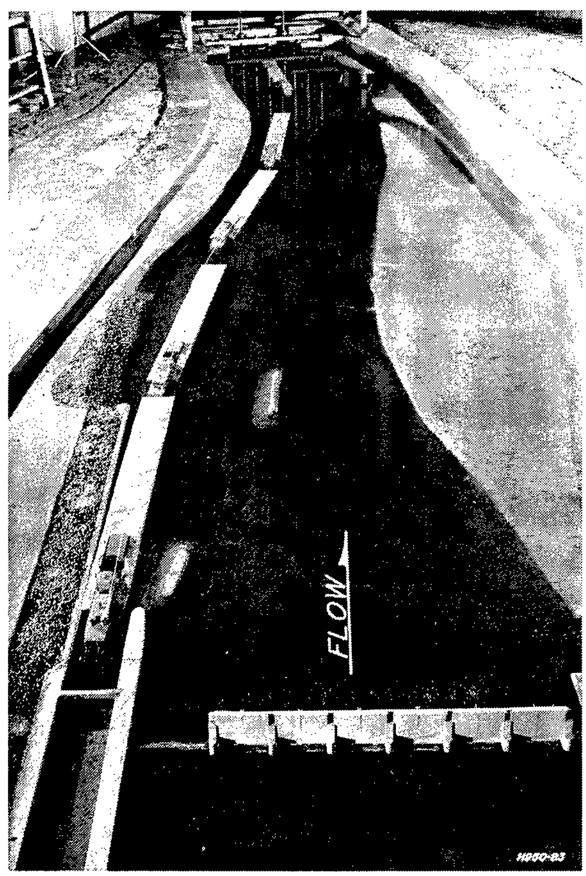


Photo 26. Plan B-Modified, looking downstream, discharge 55,000 cfs, showing path of downbound tow leaving lock along left bank

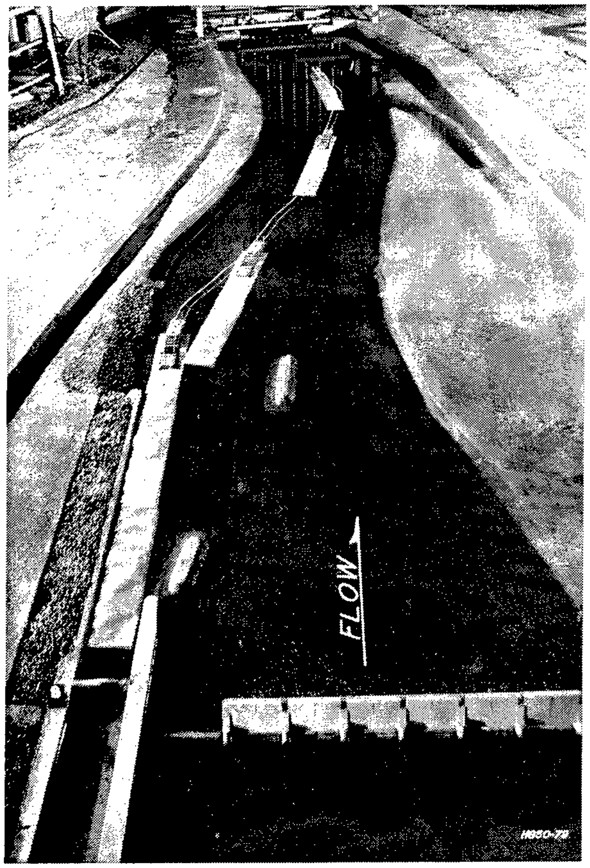


Photo 27. Plan B-Modified, looking downstream, discharge 22,500 cfs, showing path of upbound tow approaching lock from midchannel

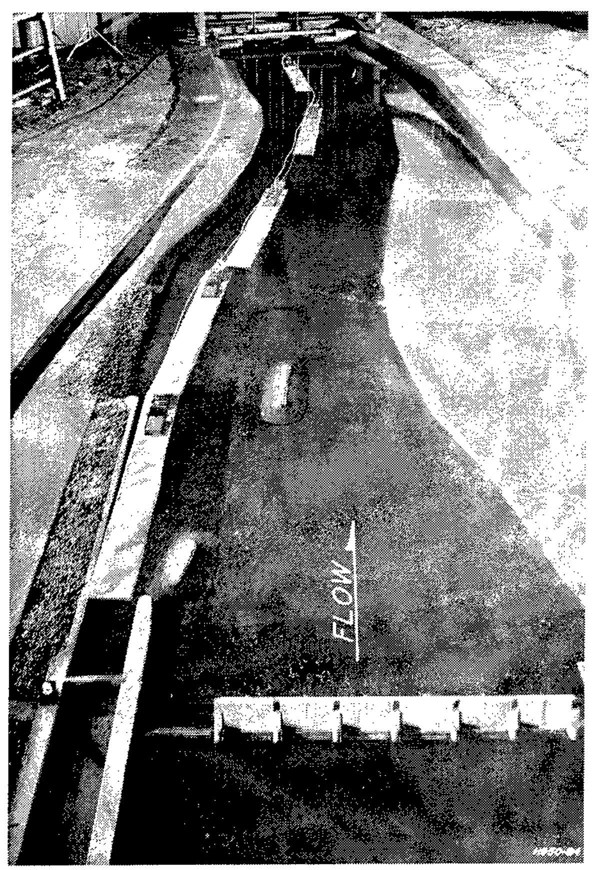


Photo 28. Plan B-Modified, looking downstream, discharge 50,000 cfs, showing path of upbound tow approaching lock

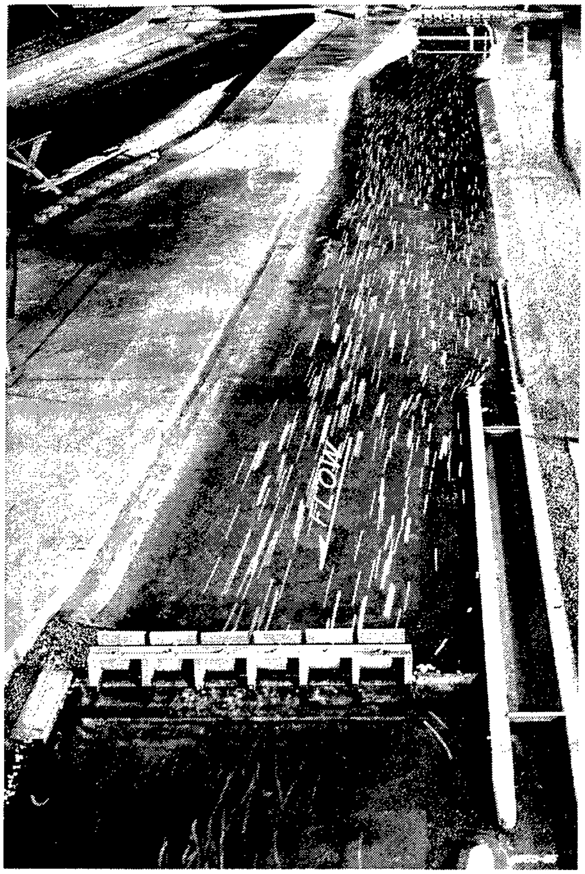
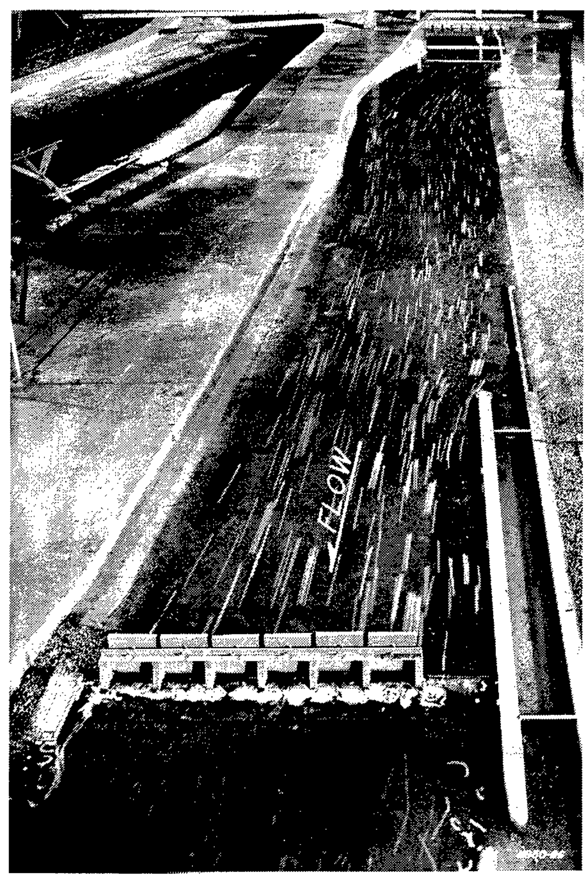


Photo 29. Plan D, looking upstream, discharge 22,500 cfs, confetti showing surface current patterns in the upper approach to the lock

Photo 30. Plan D, looking upstream, discharge 55,000 cfs, confetti showing surface current patterns in the upper approach to the lock



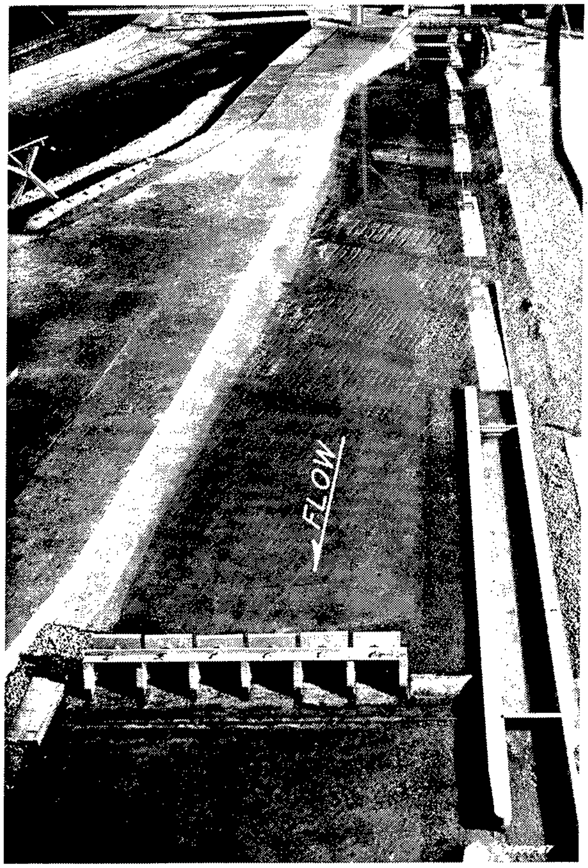
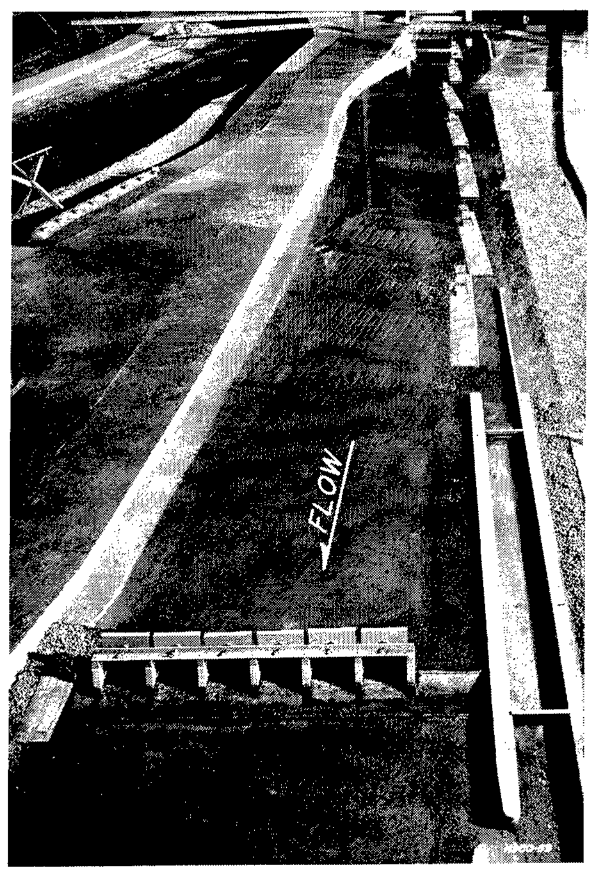


Photo 31. Plan D, looking upstream, discharge 22,500 cfs, showing path of downbound tow approaching lock

Photo 32. Plan D, looking upstream, discharge 55,000 cfs, showing path of downbound tow approaching lock. Note movement away from guide wall as tow reduces speed



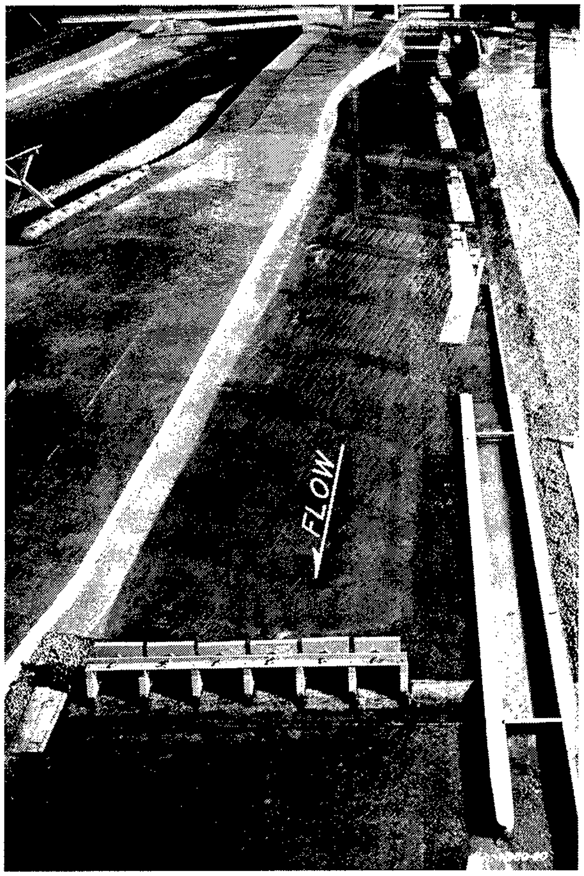


Photo 33. Plan D, looking upstream, discharge 55,000 cfs, showing path of downbound tow approaching lock. Note maneuvering in approach

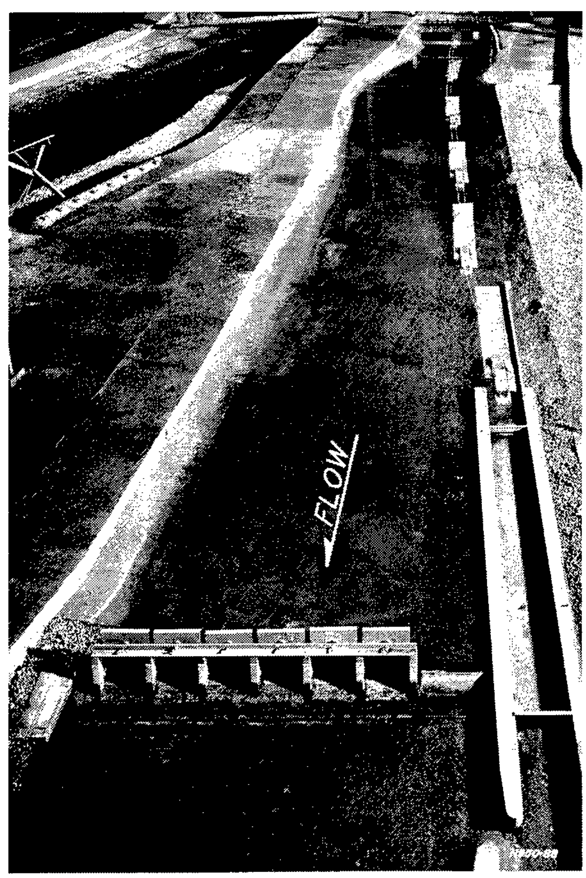


Photo 34. Plan D, looking upstream, discharge 22,500 cfs, showing path of upbound tow leaving lock

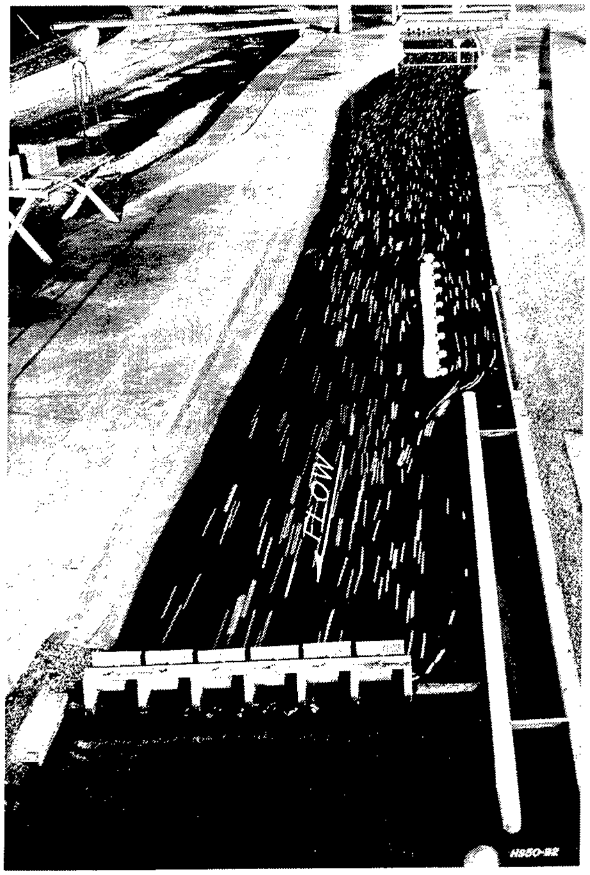


Photo 35. Plan D-Modified, looking upstream, discharge 22,500 cfs, confetti showing surface current patterns in the upper approach to the lock

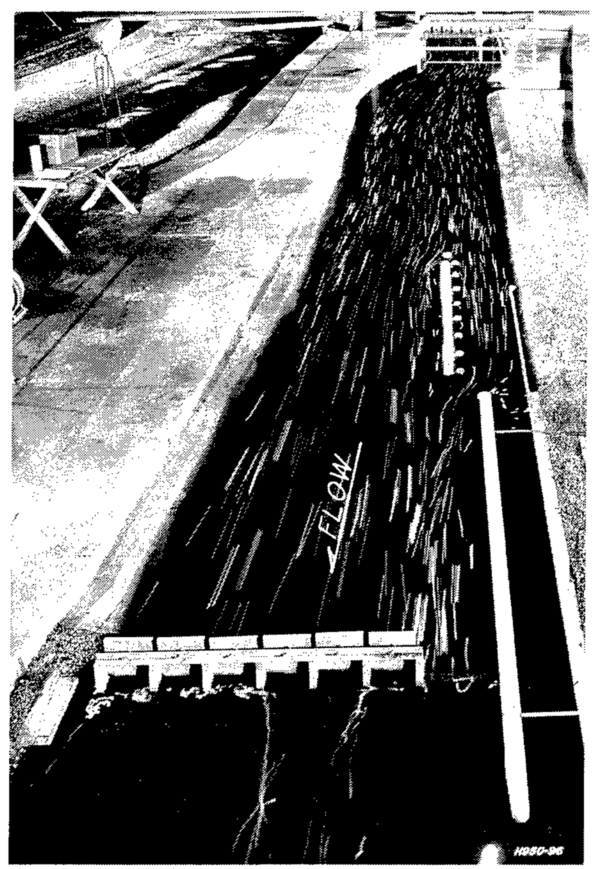


Photo 36. Plan D-Modified, looking upstream, discharge 55,000 cfs, confetti showing surface current patterns in the upper approach to the lock

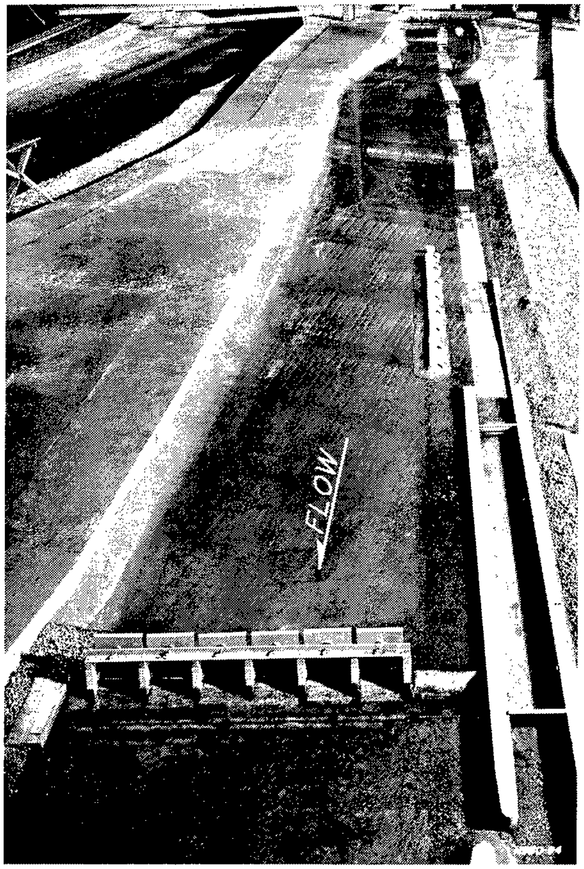


Photo 37. Plan D-Modified, looking upstream, discharge 22,500 cfs, showing path of downbound tow approaching lock

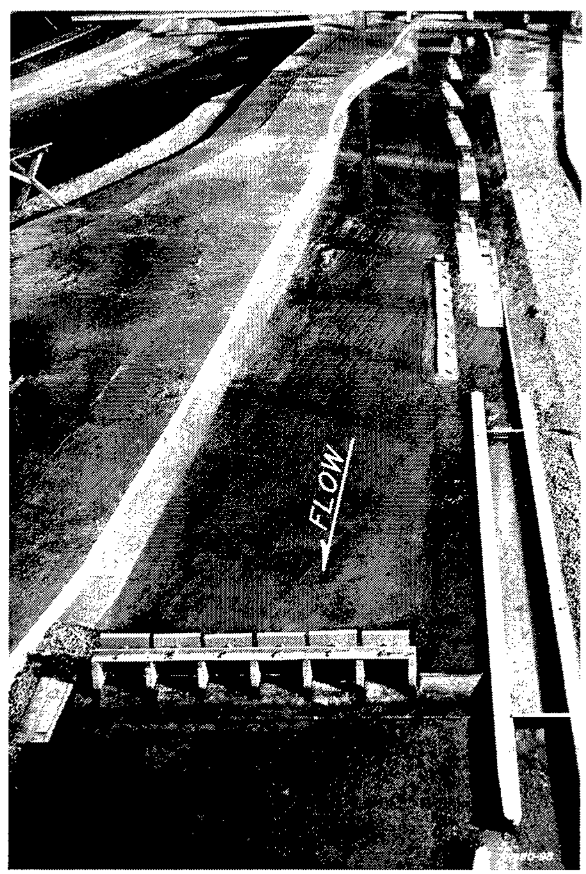


Photo 38. Plan D-Modified, looking upstream, discharge 55,000 cfs, showing path of downbound tow approaching lock. Note tow landing on guide wall by maneuvering in lock approach

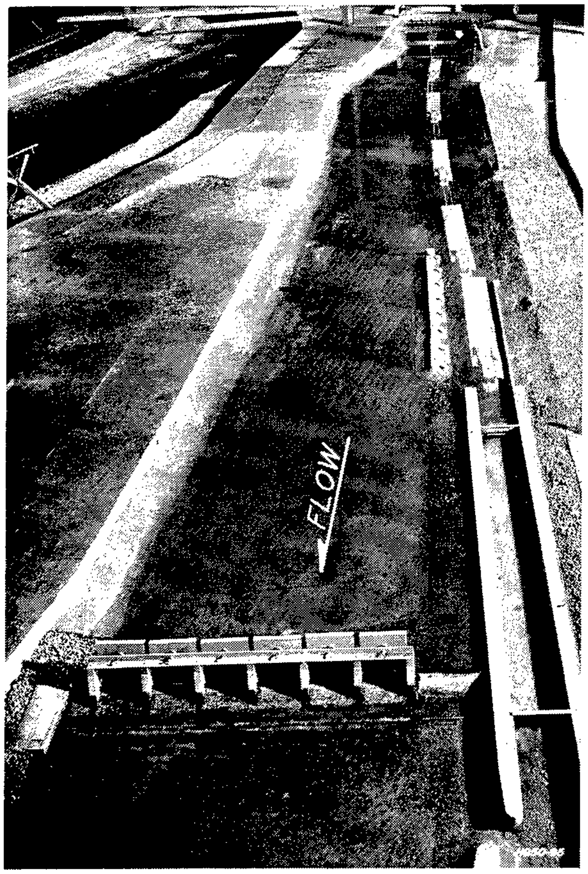


Photo 39. Plan D-Modified, looking upstream, discharge 22,500 cfs, showing path of upbound tow leaving lock

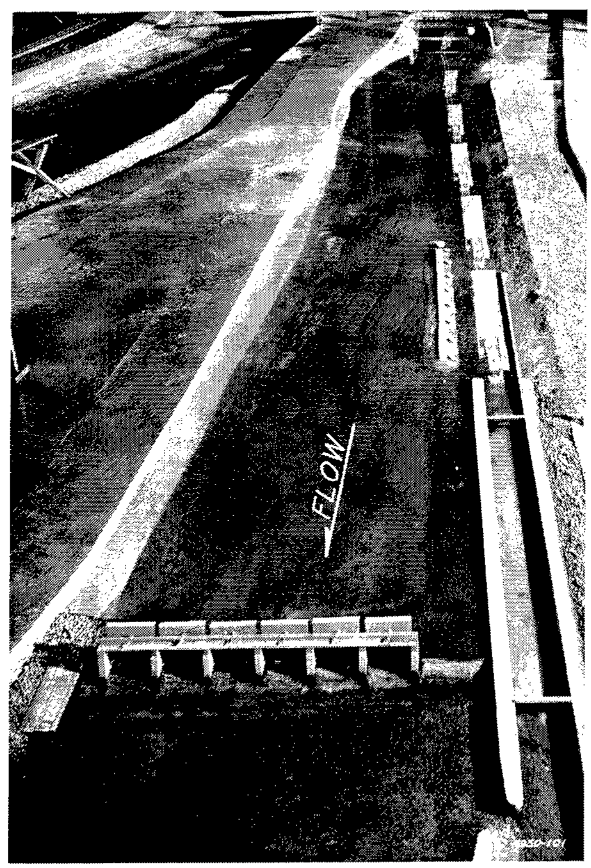


Photo 40. Plan D-Modified, looking upstream, discharge 55,000 cfs, showing path of upbound tow leaving lock

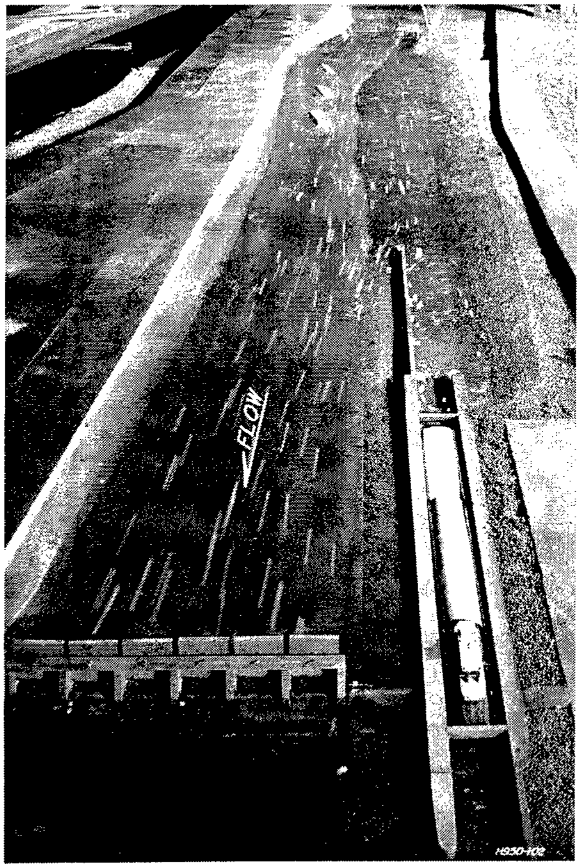


Photo 41. Plan E, looking upstream, discharge 22,500 cfs, confetti showing surface current patterns in upper lock approach

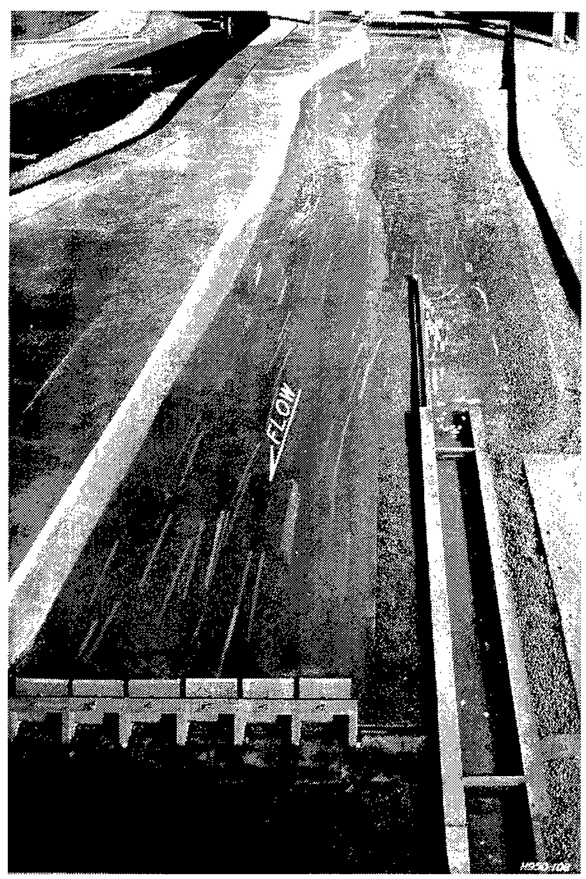


Photo 42. Plan E, looking upstream, discharge 55,000 cfs, confetti showing surface current patterns in upper lock approach

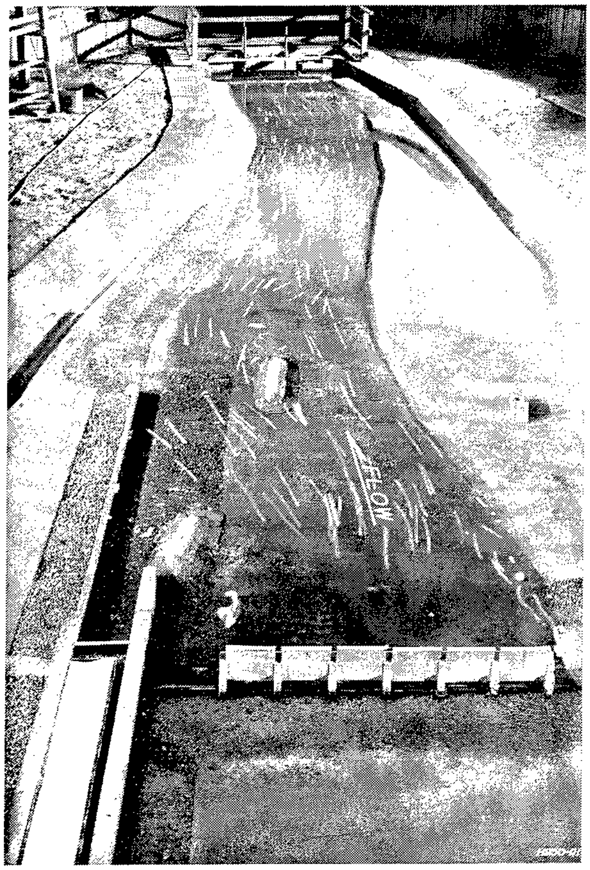


Photo 43. Plan E, looking downstream, discharge 22,500 cfs, confetti showing surface current patterns in lower lock approach

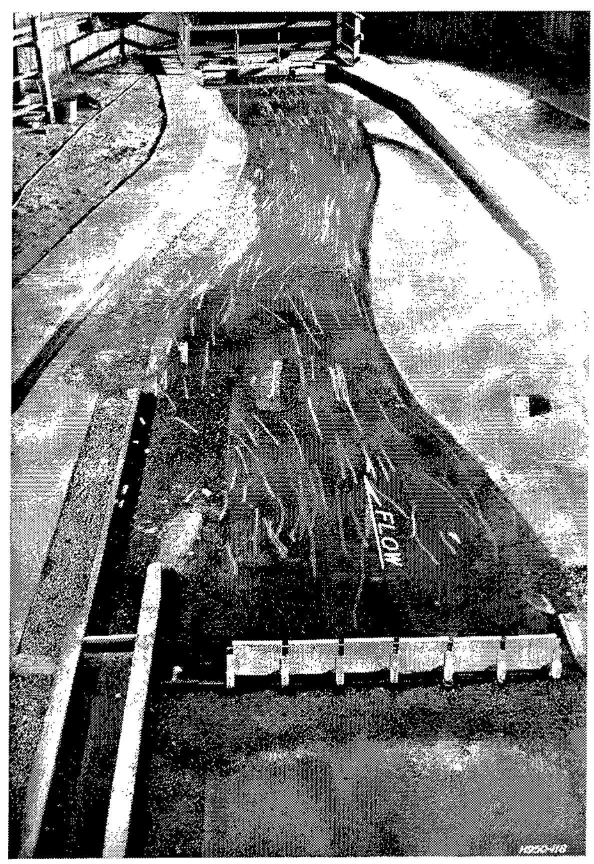


Photo 44. Plan E, looking downstream, discharge 55,000 cfs, confetti showing surface current patterns in lower lock approach

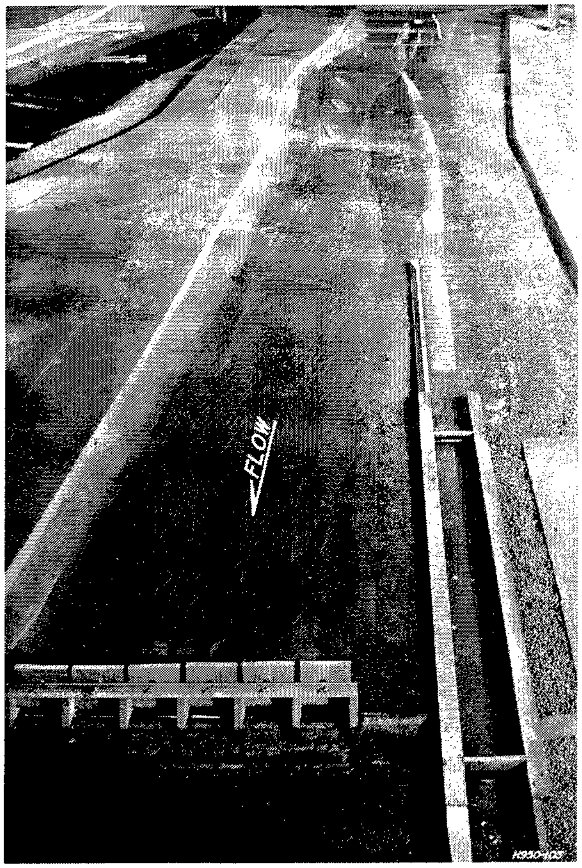


Photo 45. Plan E, looking upstream, discharge 22,500 cfs, showing path of downbound tow approaching lock

Photo 46. Plan E, looking upstream, discharge 55,000 cfs, showing path of downbound tow approaching lock

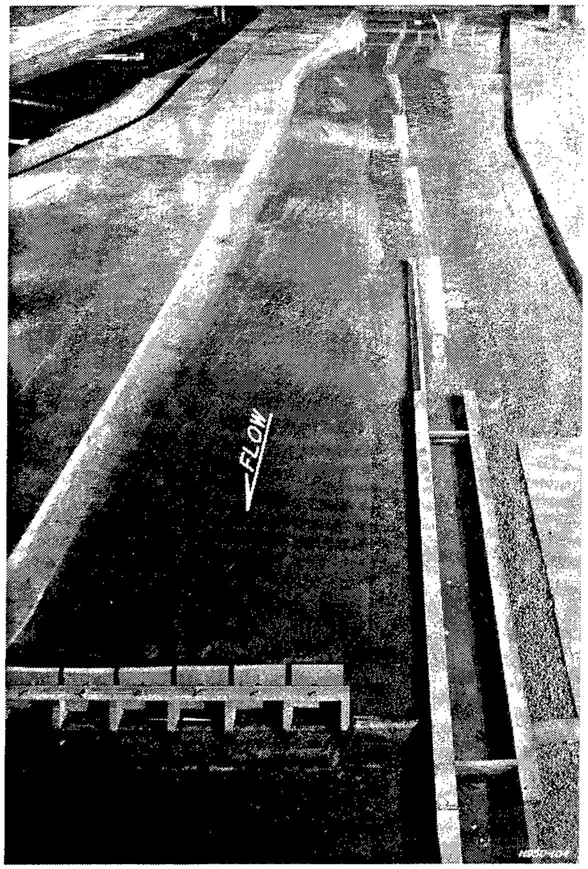


Photo 47. Plan E, looking upstream, discharge 22,500 cfs, showing path of upbound tow leaving lock

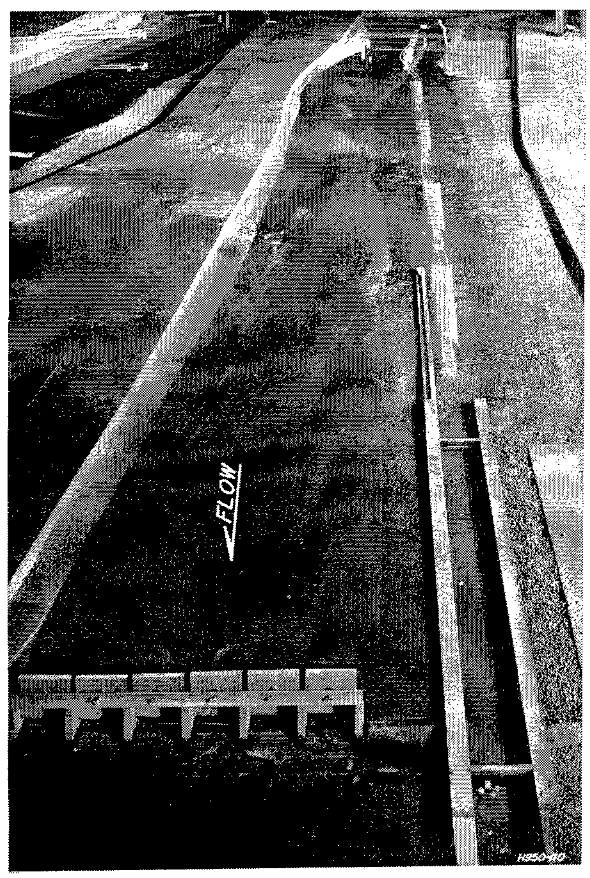


Photo 48. Plan E, looking upstream, discharge 55,000 cfs, showing path of upbound tow leaving lock

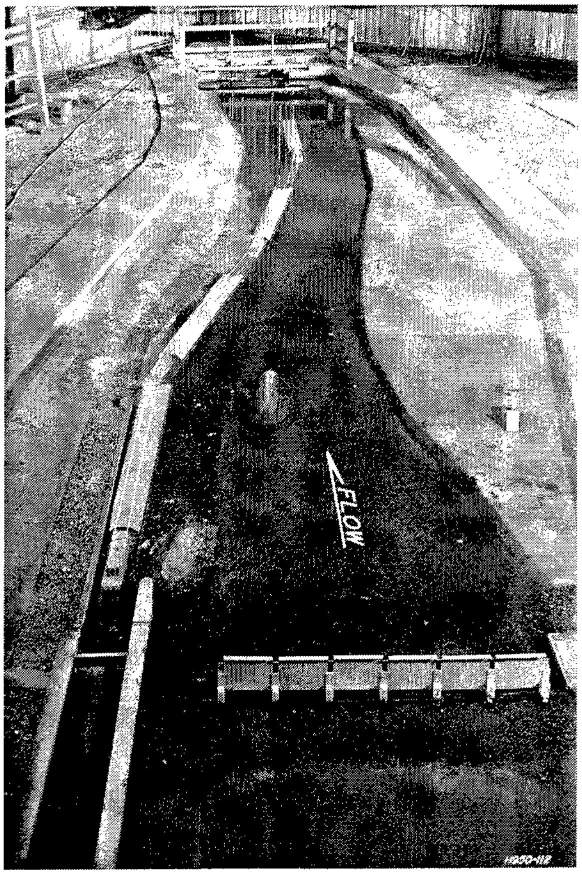
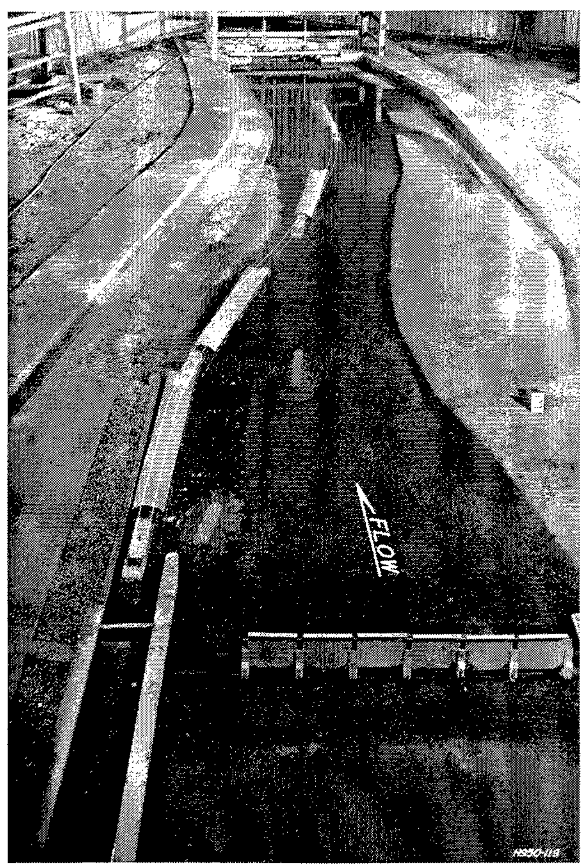


Photo 49. Plan E, looking downstream, discharge 22,500 cfs, showing path of downbound tow leaving lock

Photo 50. Plan E, looking downstream, discharge 55,000 cfs, showing path of downbound tow leaving lock



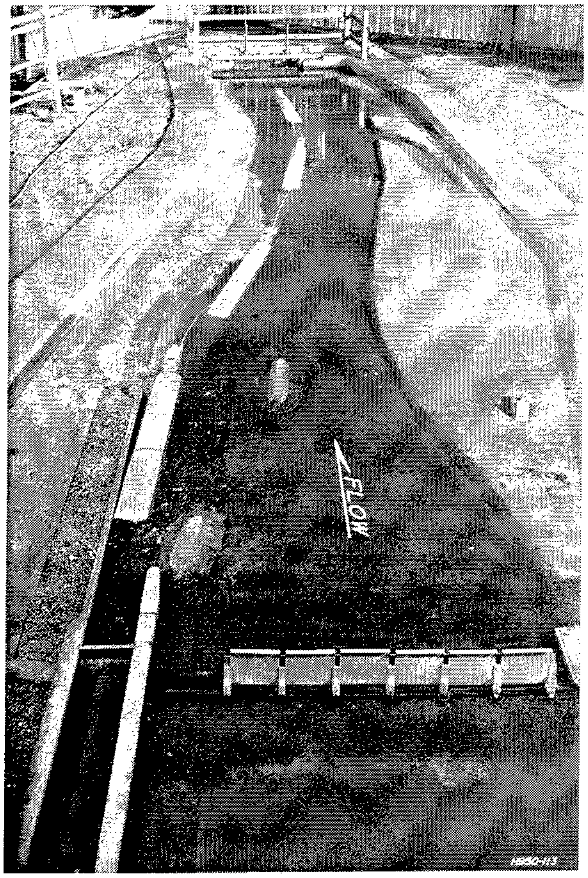


Photo 51. Plan E, looking downstream, discharge 22,500 cfs, showing path of upbound tow approaching lock

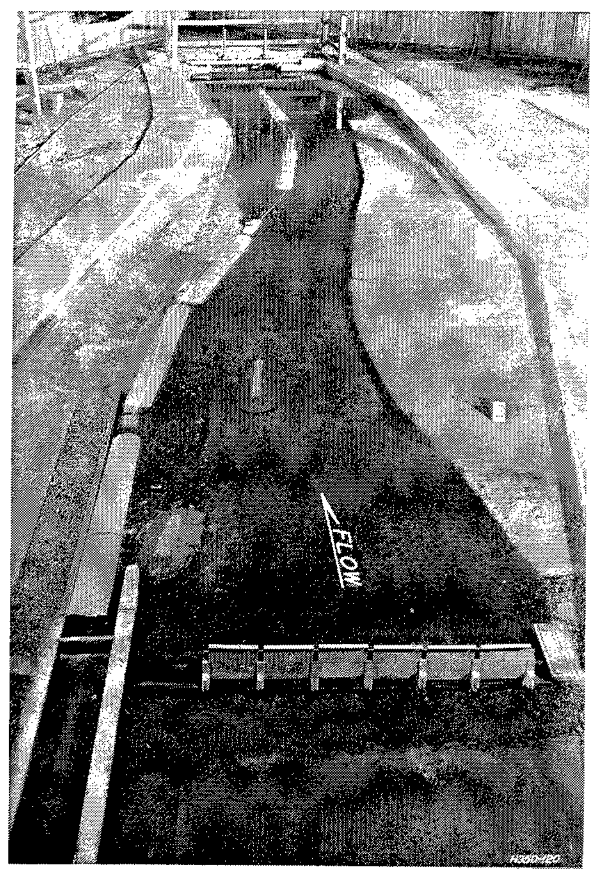


Photo 52. Plan E, looking downstream, discharge 55,000 cfs, showing path of upbound tow approaching lock

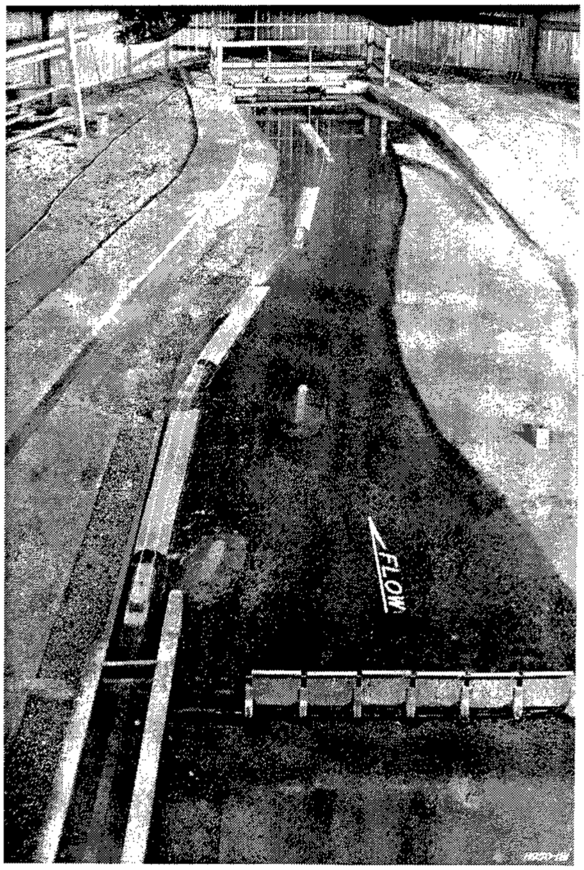


Photo 53. Plan E, drawdown conditions, looking downstream, discharge 55,000 cfs, showing path of downbound tow leaving lock

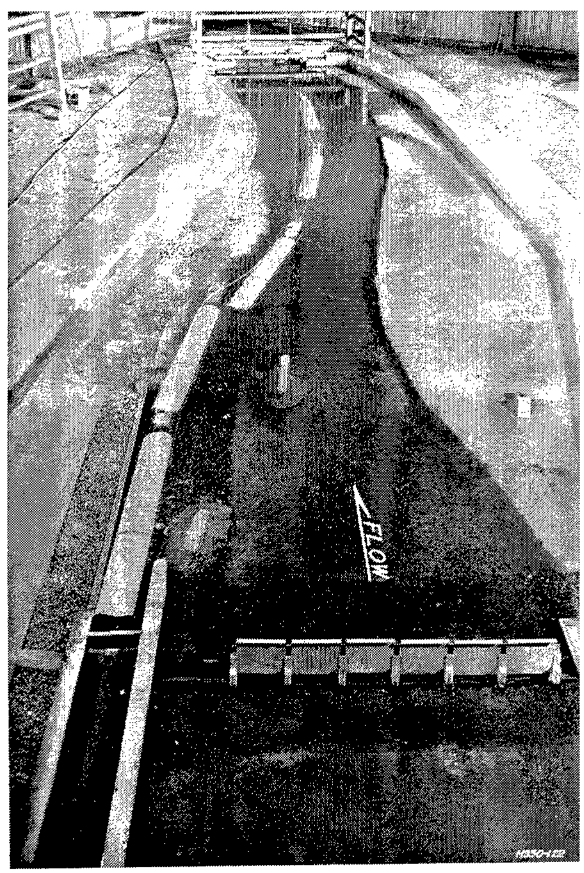


Photo 54. Plan E, drawdown conditions, looking downstream, discharge 55,000 cfs, showing path of upbound tow approaching lock

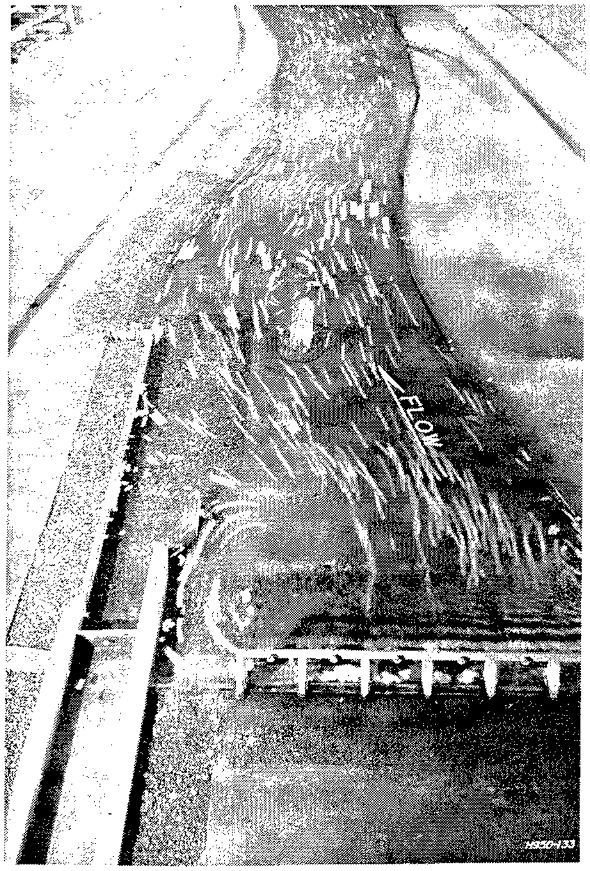


Photo 55. Plan E-Modified, looking downstream, discharge 22,500 cfs, confetti showing surface current patterns in lower lock approach

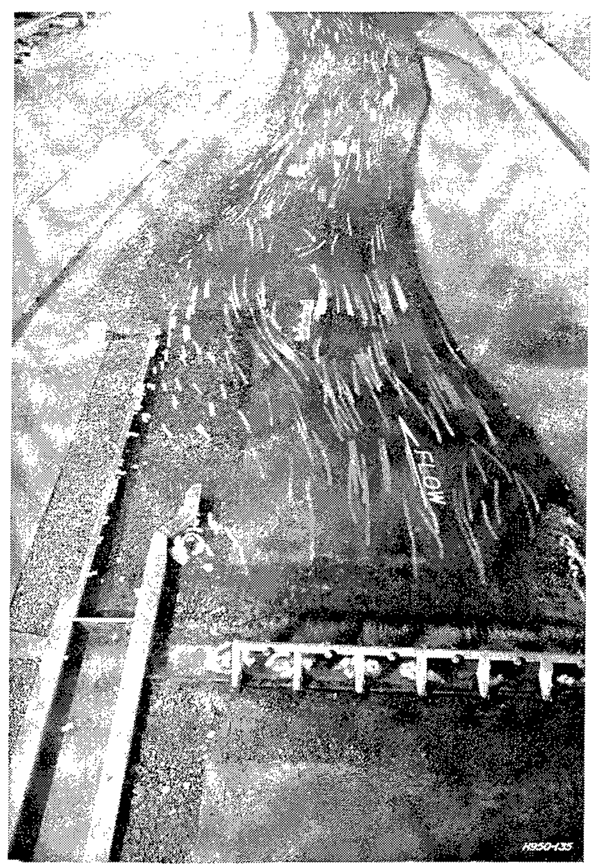


Photo 56. Plan E-Modified, looking downstream, discharge 55,000 cfs, confetti showing surface current patterns in lower lock approach

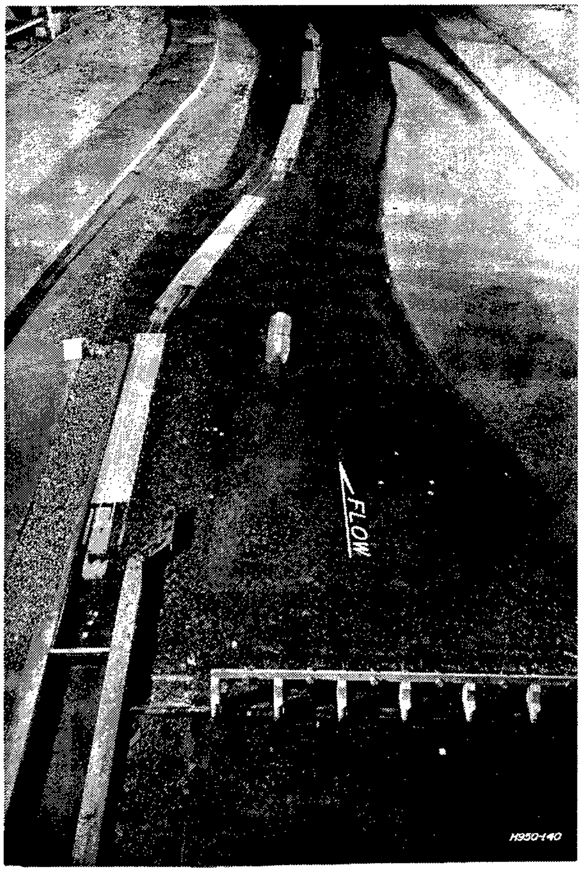


Photo 57. Plan E-Modified, looking downstream, discharge 22,500 cfs, showing path of downbound tow leaving lock

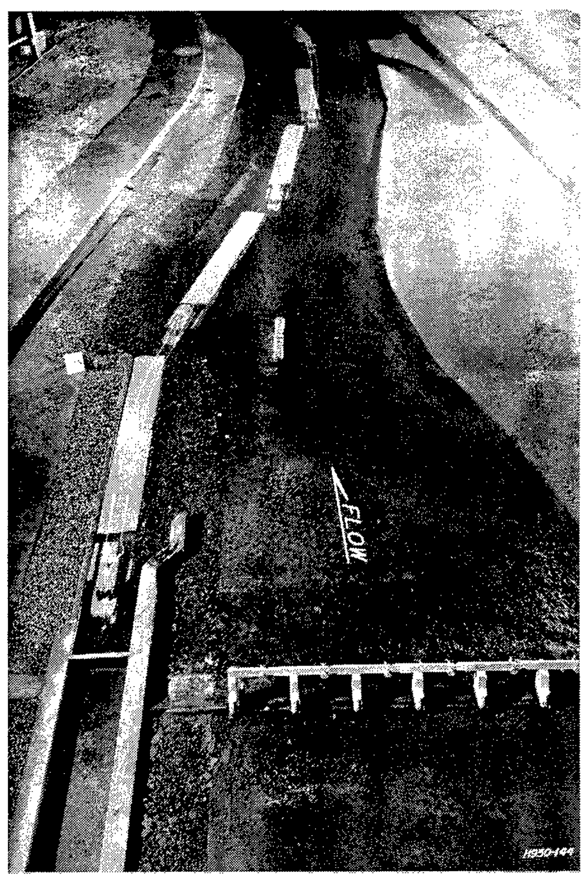


Photo 58. Plan E-Modified, looking downstream, discharge 55,000 cfs, showing path of downbound tow leaving lock

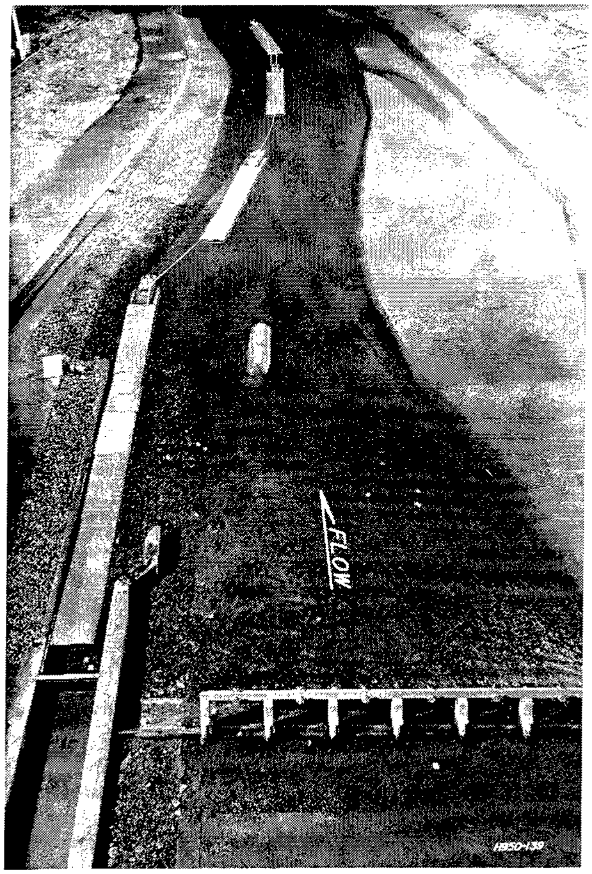


Photo 59. Plan E-Modified, looking downstream, discharge 22,500 cfs, showing path of upbound tow approaching lock

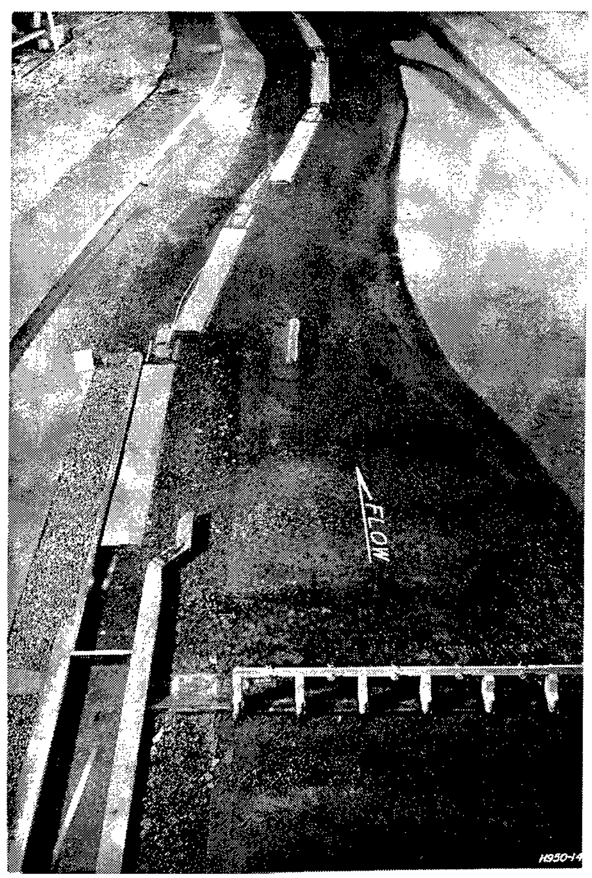


Photo 60. Plan E-Modified, looking downstream, discharge 55,000 cfs, showing path of upbound tow approaching lock

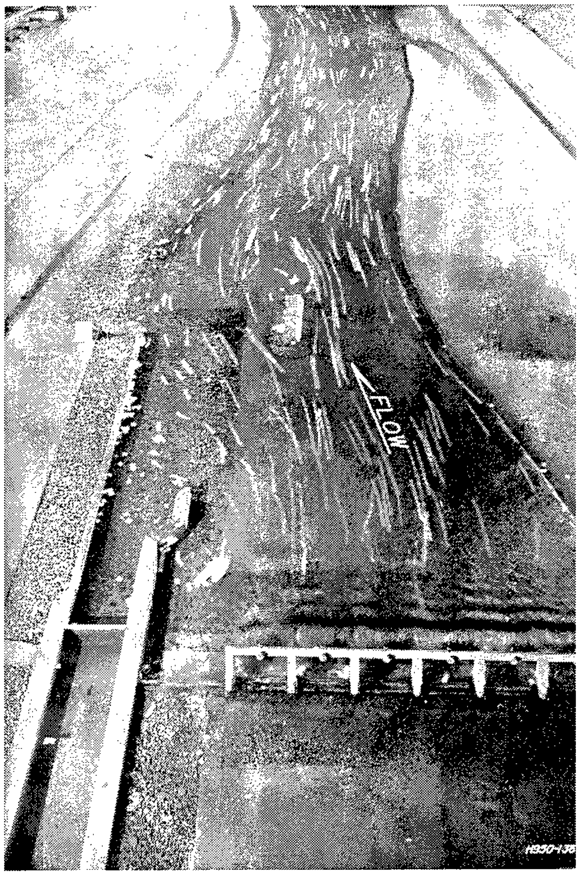
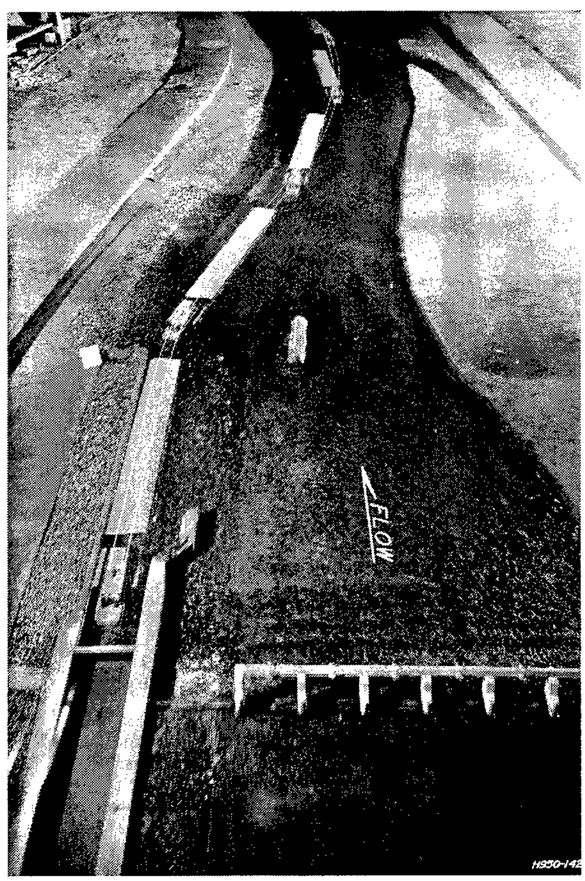


Photo 61. Plan E-Modified, drawdown conditions, looking downstream, discharge 55,000 cfs, confetti showing surface current patterns in lower lock approach

Photo 62. Plan E-Modified, drawdown condition, looking downstream, discharge 55,000 cfs, showing path of downbound tow leaving lock



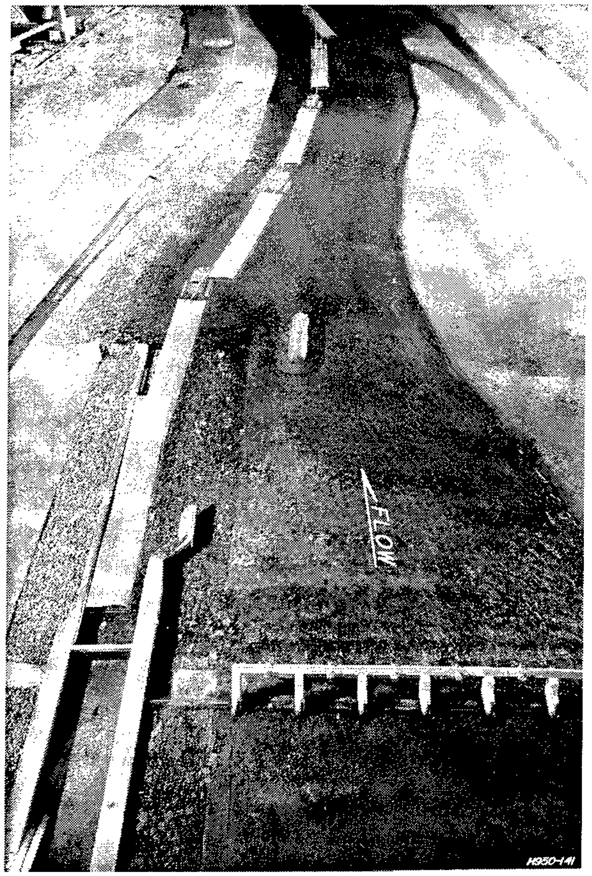


Photo 63. Plan E-Modified, drawdown condition, looking downstream, discharge 55,000 cfs, showing path of upbound tow approaching lock

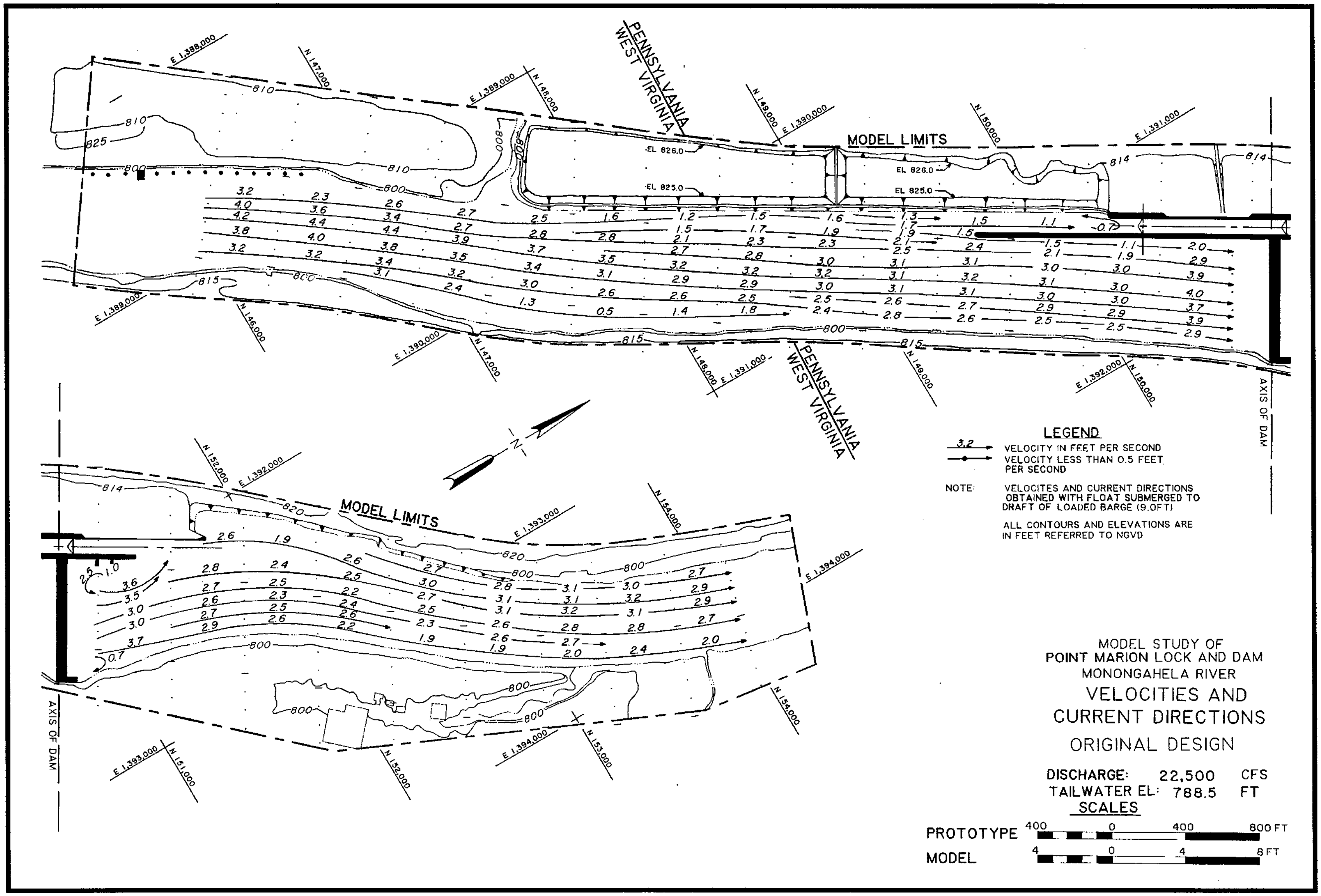
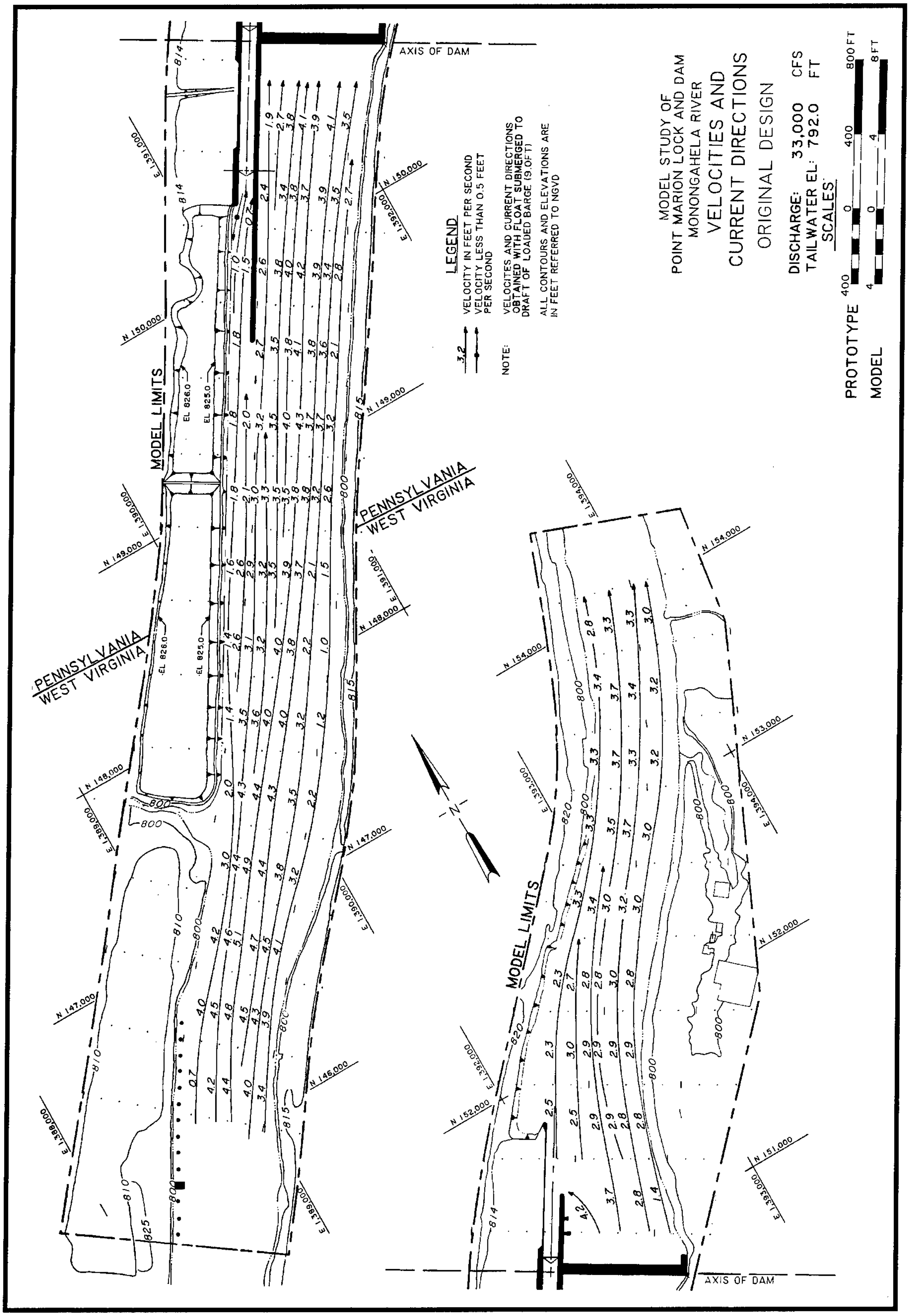

MODEL LIMITS
PENNSYLVANIA
WEST VIRGINIA
AXIS OF DAM
EL 826.0
EL 825.0
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE: VELOCITES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER
VELOCITIES AND
CURRENT DIRECTIONS
ORIGINAL DESIGN
DISCHARGE: 22,500 CFS
TAILWATER EL: 788.5 FT
SCALES
PROTOTYPE 400 0 400 800 FT
MODEL 4 0 4 8 FT

Plate 1



MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER
VELOCITIES AND
CURRENT DIRECTIONS
ORIGINAL DESIGN
DISCHARGE: 33,000 CFS
TAILWATER EL: 792.0 FT
SCALES
PROTOTYPE 400 0 400 800 FT
MODEL 4 0 4 8 FT
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE: VELOCITES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
AXIS OF DAM
MODEL LIMITS
PENNSYLVANIA
WEST VIRGINIA
EL 826.0
EL 825.0
N

Plate 2

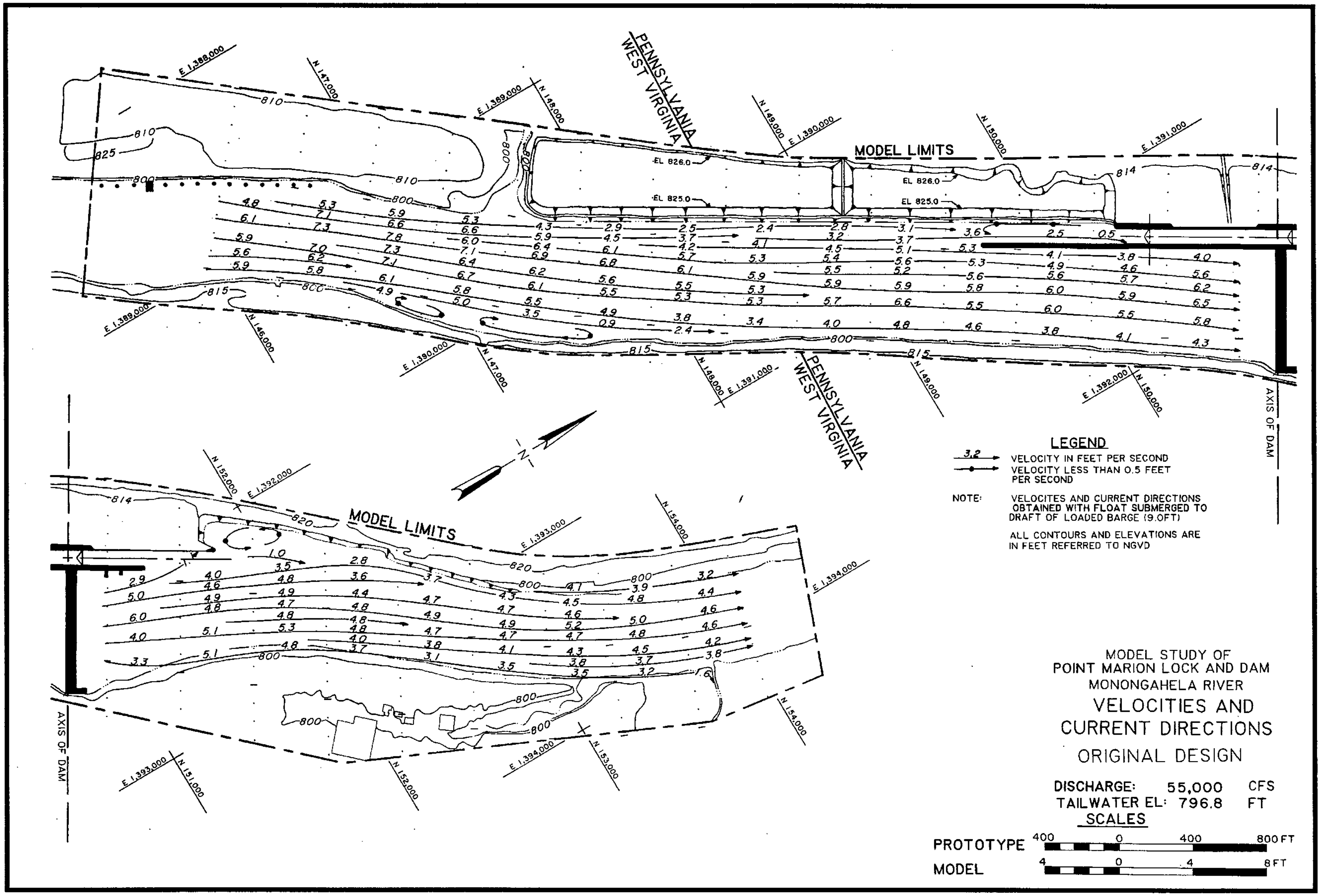

MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER
VELOCITIES AND
CURRENT DIRECTIONS
ORIGINAL DESIGN
DISCHARGE: 55,000 CFS
TAILWATER EL: 796.8 FT
SCALES
PROTOTYPE 400 0 400 800 FT
MODEL 4 0 4 8 FT
LEGEND
3.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE: VELOCITES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
MODEL LIMITS
AXIS OF DAM
PENNSYLVANIA
WEST VIRGINIA
EL 826.0
EL 825.0
N

Plate 3

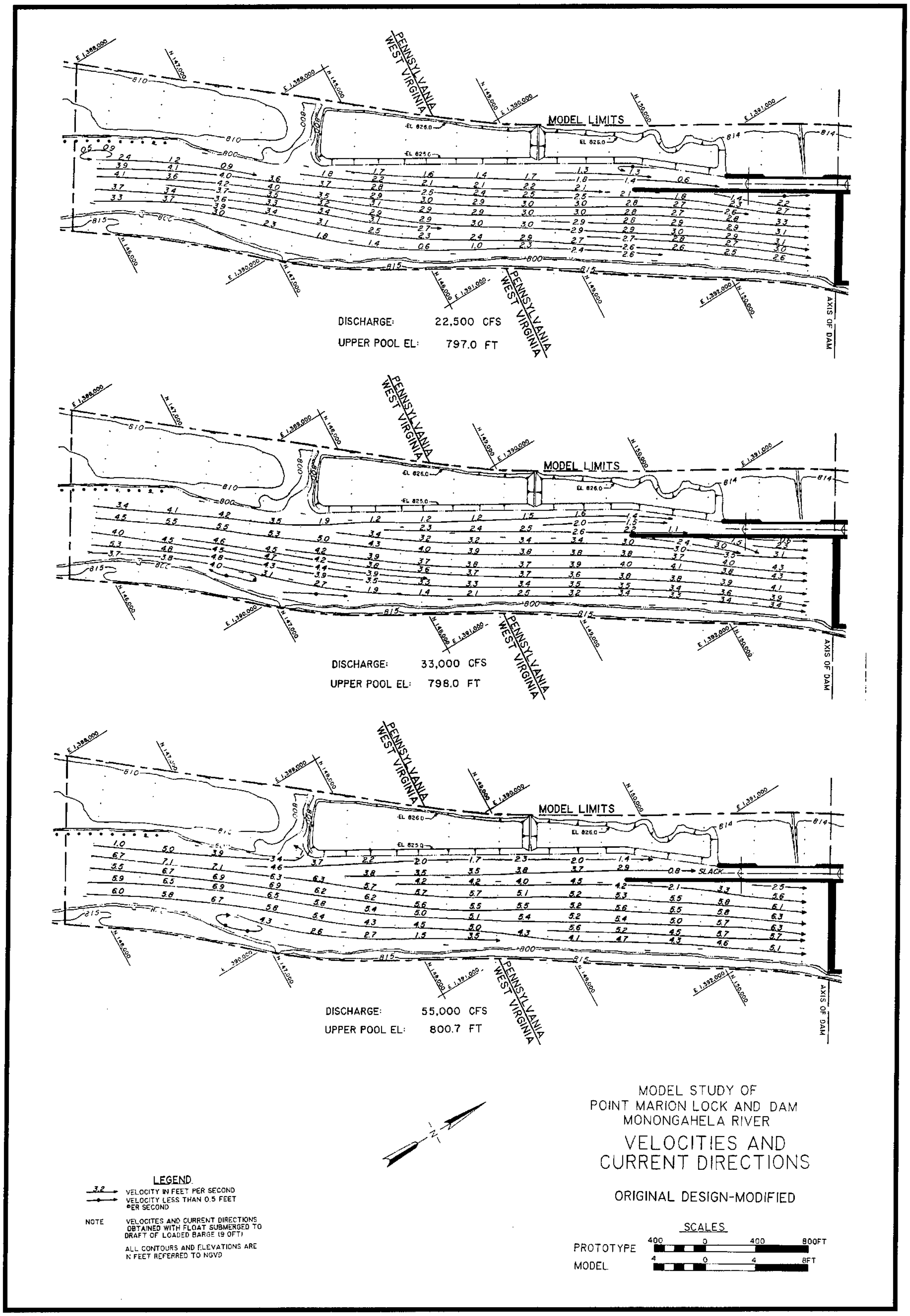
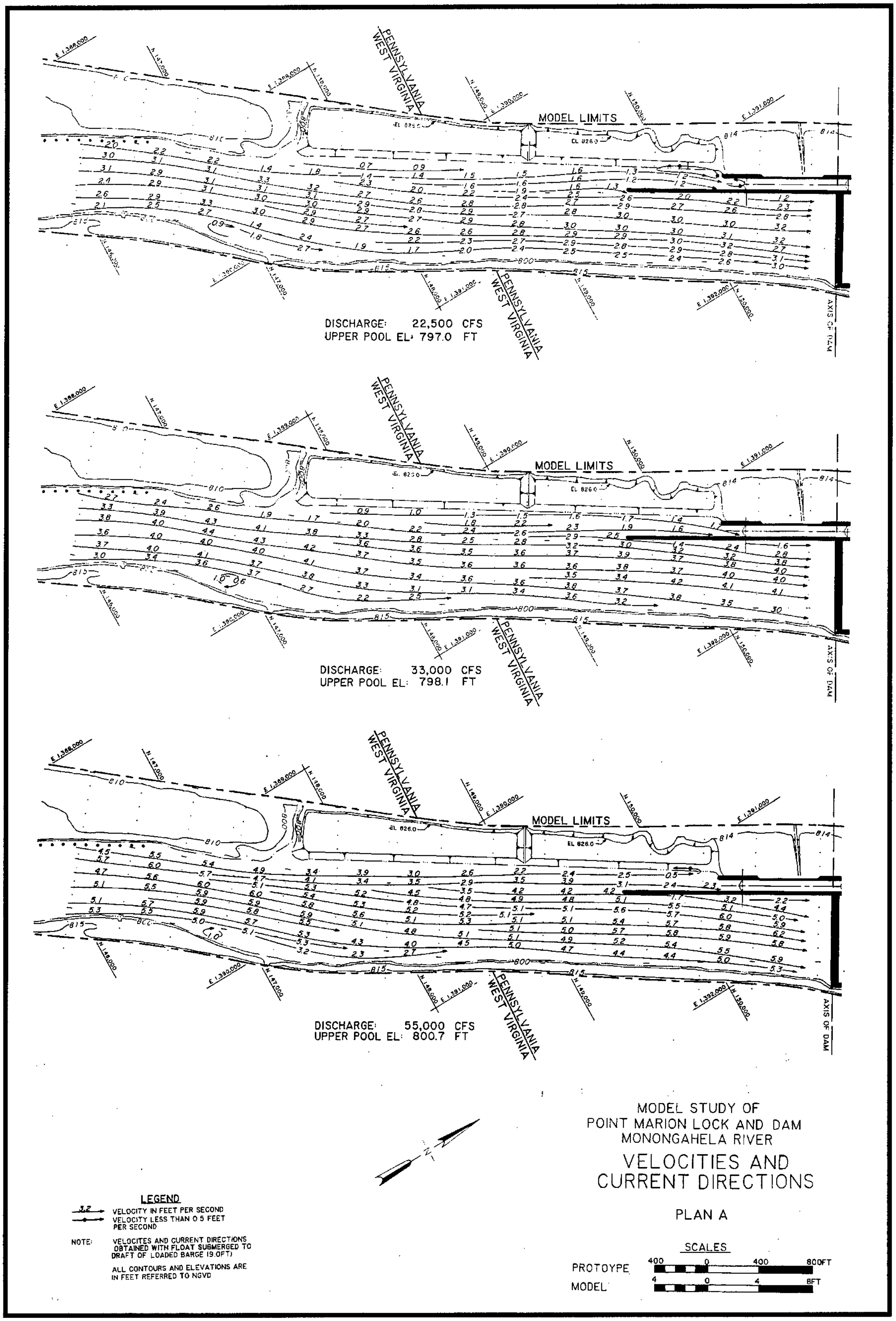

PENNSYLVANIA
WEST VIRGINIA
MODEL LIMITS
AXIS OF DAM
DISCHARGE: 22,500 CFS
UPPER POOL EL: 797.0 FT
DISCHARGE: 33,000 CFS
UPPER POOL EL: 798.0 FT
DISCHARGE: 55,000 CFS
UPPER POOL EL: 800.7 FT
SLACK
MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER
VELOCITIES AND
CURRENT DIRECTIONS
ORIGINAL DESIGN-MODIFIED
LEGEND
3.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
SCALES
PROTOTYPE 400 0 400 800FT
MODEL 4 0 4 8FT

Plate 4


MODEL LIMITS
PENNSYLVANIA
WEST VIRGINIA
AXIS OF DAM
DISCHARGE: 22,500 CFS
UPPER POOL EL: 797.0 FT
DISCHARGE: 33,000 CFS
UPPER POOL EL: 798.1 FT
DISCHARGE: 55,000 CFS
UPPER POOL EL: 800.7 FT
MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER
VELOCITIES AND
CURRENT DIRECTIONS
PLAN A
LEGEND
3.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
SCALES
PROTOYPE 400 0 400 800FT
MODEL 4 0 4 8FT

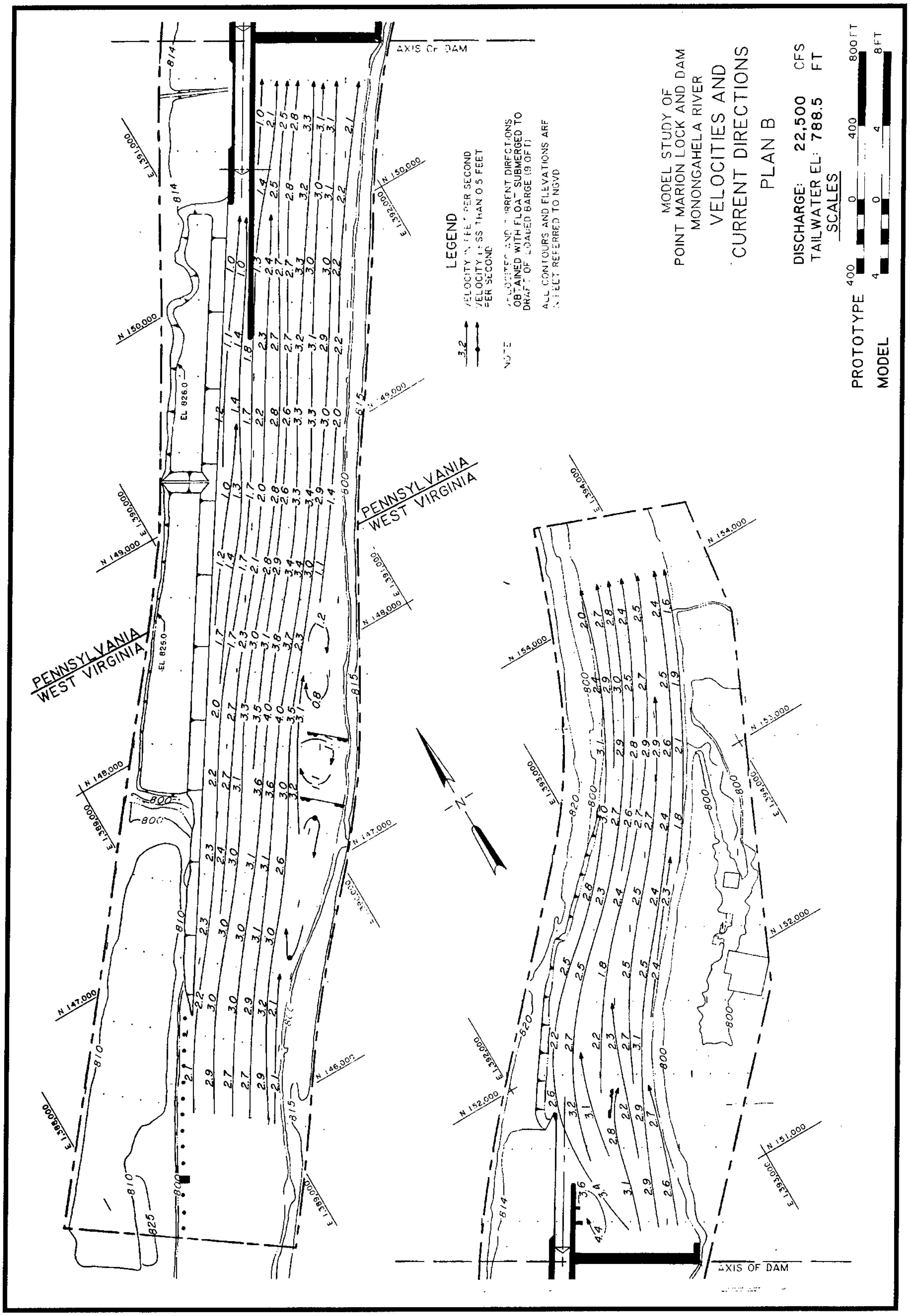
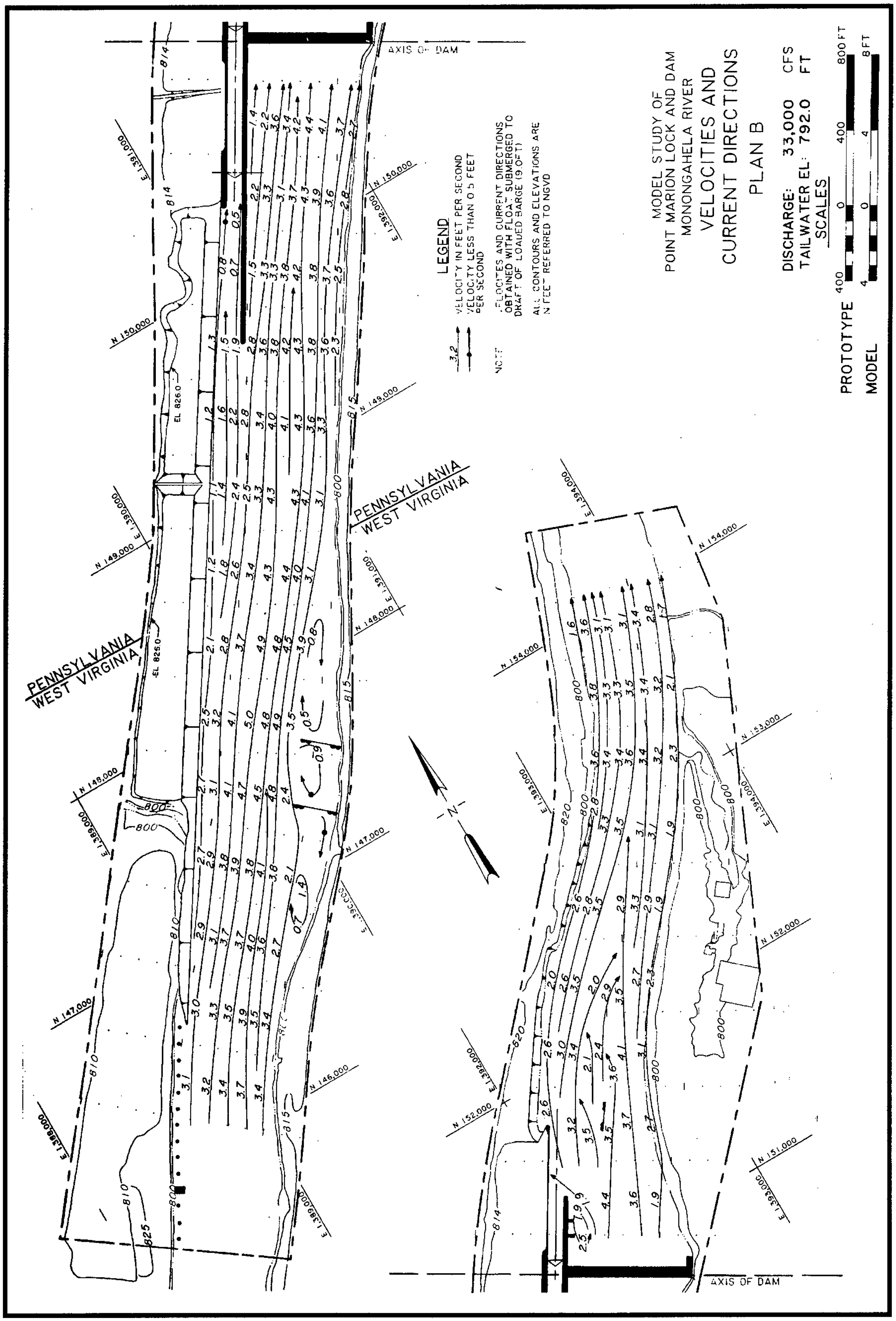

MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER
VELOCITIES AND
CURRENT DIRECTIONS
PLAN B
DISCHARGE: 22,500 CFS
TAILWATER EL: 788.5 FT
SCALES
PROTOTYPE 400 0 400 800 FT
MODEL 4 0 4 8 FT
LEGEND
3.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
AXIS OF DAM
PENNSYLVANIA
WEST VIRGINIA
EL 826.0
EL 825.0
N 150,000
N 149,000
N 148,000
N 147,000
N 146,000
N 154,000
N 153,000
N 152,000
N 151,000

Plate 6



MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER
VELOCITIES AND
CURRENT DIRECTIONS
PLAN B
DISCHARGE: 33,000 CFS
TAILWATER EL: 792.0 FT
SCALES
PROTOTYPE 400 0 400 800 FT
MODEL 4 0 4 8 FT
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
AXIS OF DAM
PENNSYLVANIA
WEST VIRGINIA

Plate 7

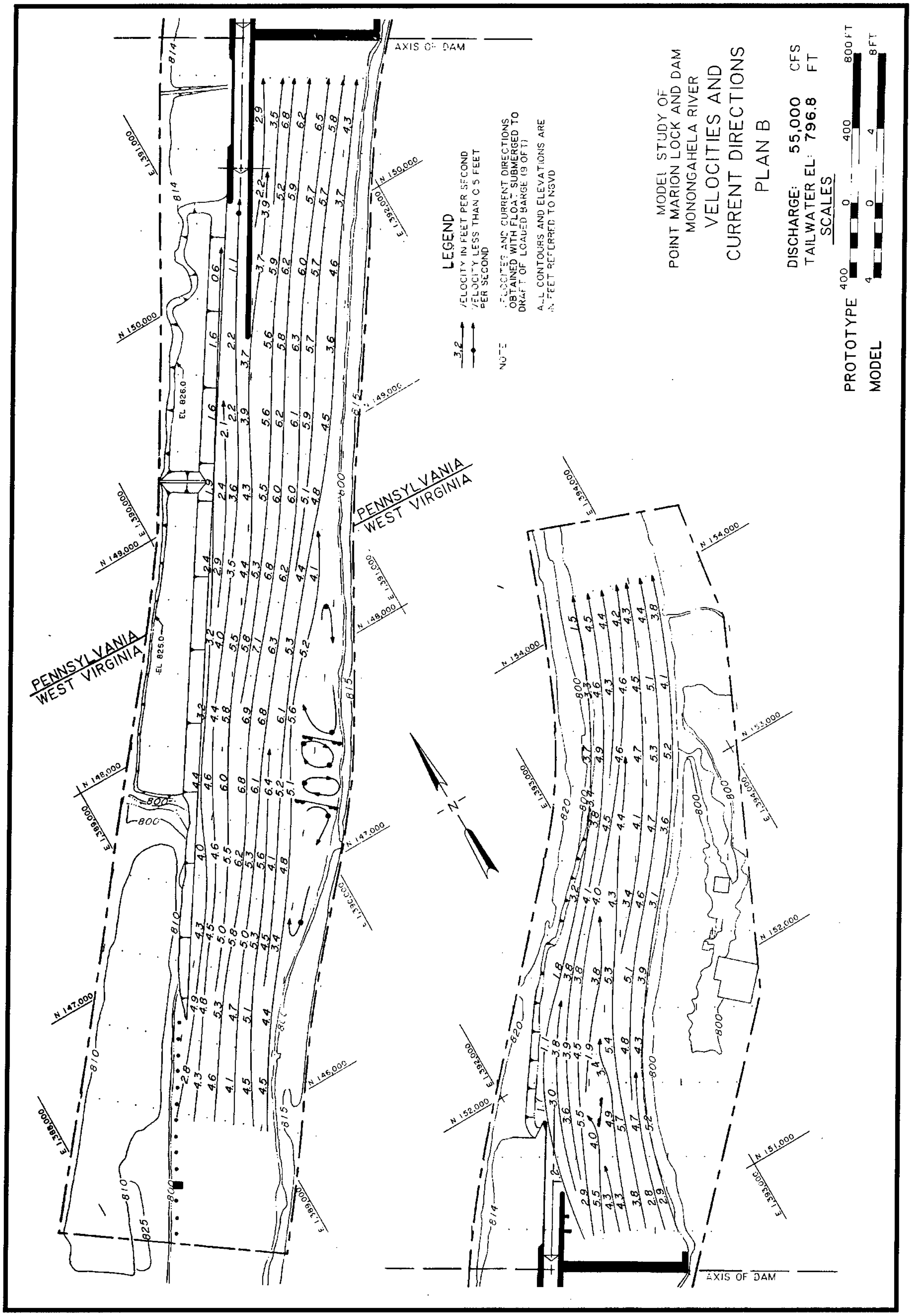
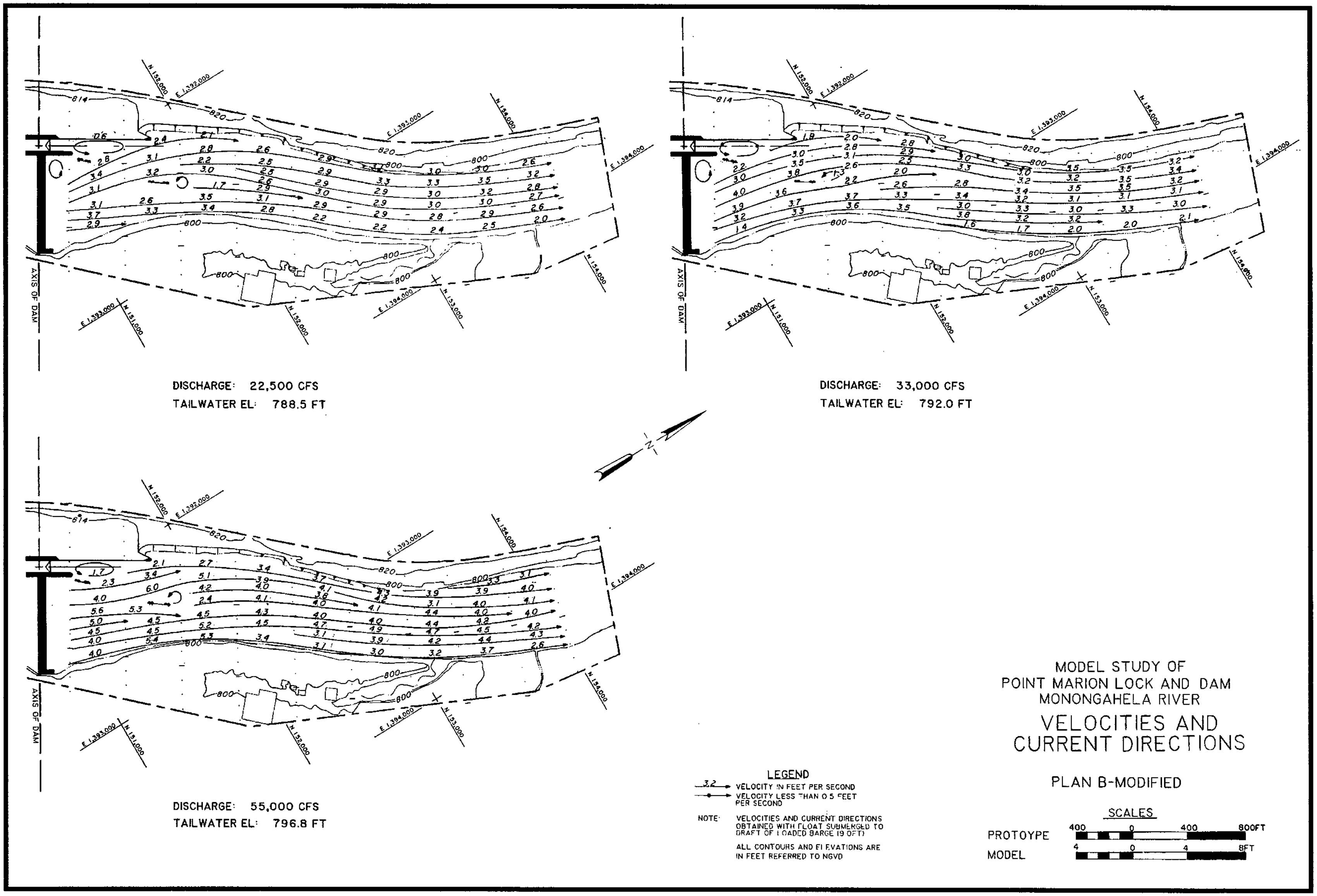

MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER
VELOCITIES AND
CURRENT DIRECTIONS
PLAN B
DISCHARGE: 55,000 CFS
TAILWATER EL: 796.8 FT
SCALES
PROTOTYPE 400 0 400 800 FT
MODEL 4 0 4 8 FT
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE:
VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
AXIS OF DAM
PENNSYLVANIA
WEST VIRGINIA
EL 826.0
EL 825.0
N

Plate 8


DISCHARGE: 22,500 CFS
TAILWATER EL: 788.5 FT
DISCHARGE: 33,000 CFS
TAILWATER EL: 792.0 FT
DISCHARGE: 55,000 CFS
TAILWATER EL: 796.8 FT
AXIS OF DAM
N
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 0 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER
VELOCITIES AND
CURRENT DIRECTIONS
PLAN B-MODIFIED
SCALES
PROTOYPE
MODEL
400 0 400 800FT
4 0 4 8FT

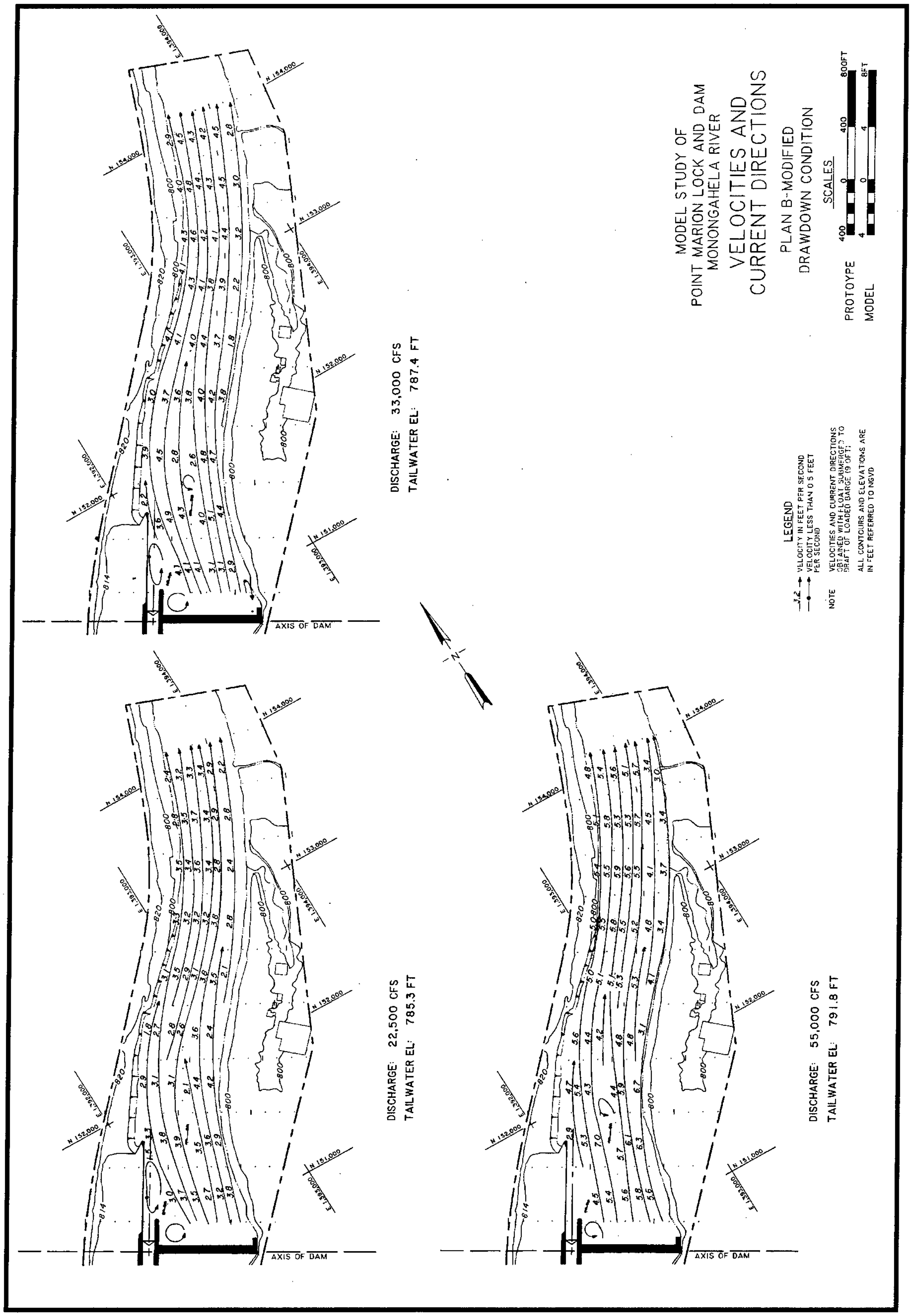
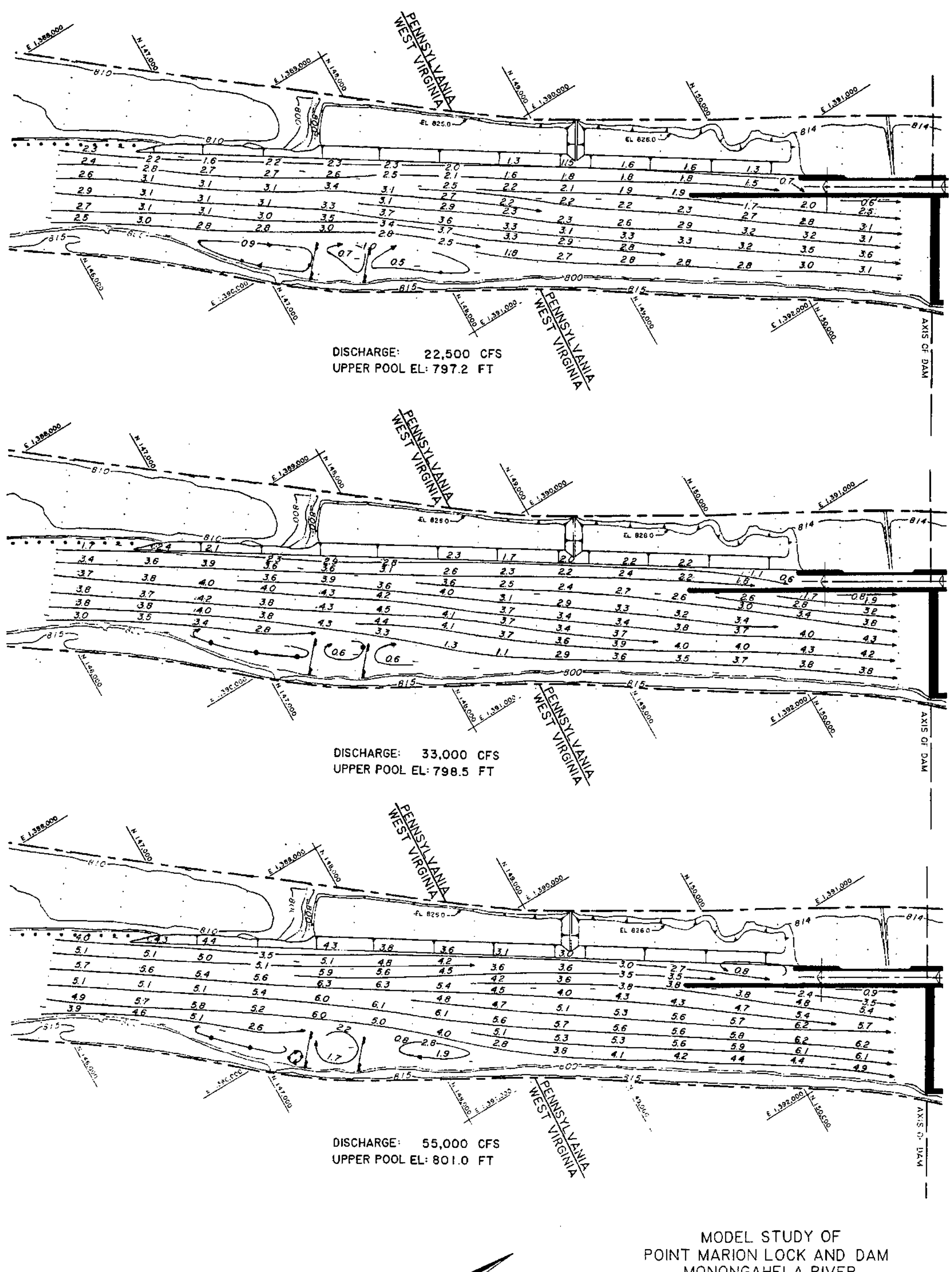

MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER
VELOCITIES AND
CURRENT DIRECTIONS
PLAN B-MODIFIED
DRAWDOWN CONDITION
SCALES
PROTOYPE 400 0 400 800FT
MODEL 4 0 4 8FT
LEGEND
3.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 0FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
DISCHARGE: 33,000 CFS
TAILWATER EL: 787.4 FT
DISCHARGE: 22,500 CFS
TAILWATER EL: 785.3 FT
DISCHARGE: 55,000 CFS
TAILWATER EL: 791.8 FT
AXIS OF DAM
N

Plate 10



MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER

VELOCITIES AND CURRENT DIRECTIONS

PLAN C

LEGEND

3.2 → VELOCITY IN FEET PER SECOND

VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT).

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOYPE 400 0 400 800FT

MODEL 4 0 4 8FT

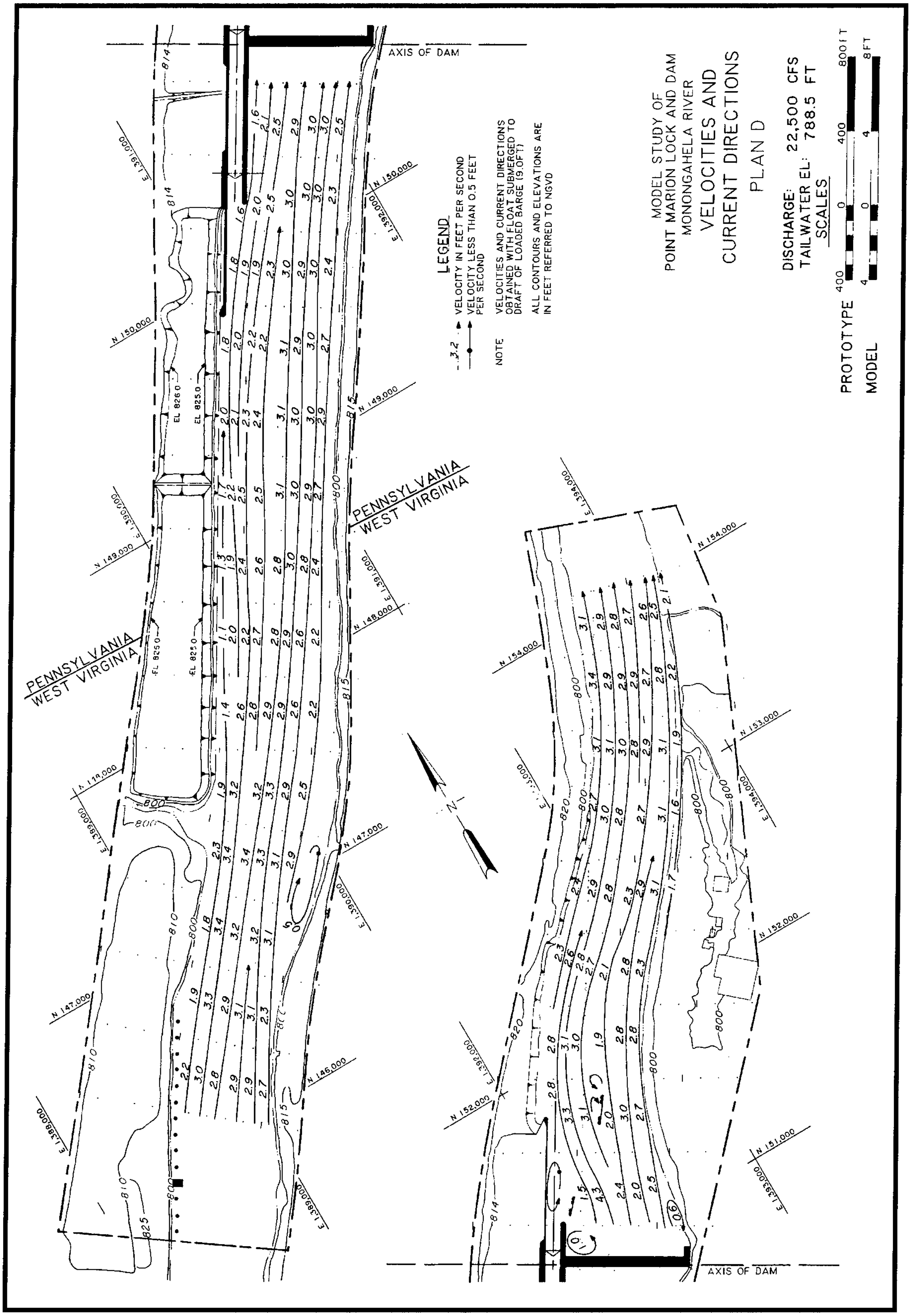

MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER
VELOCITIES AND
CURRENT DIRECTIONS
PLAN D
DISCHARGE: 22,500 CFS
TAILWATER EL: 788.5 FT
SCALES
PROTOTYPE 400 0 400 800 FT
MODEL 4 0 4 8 FT
LEGEND
3.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE
VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
AXIS OF DAM
PENNSYLVANIA
WEST VIRGINIA
N

Plate 12

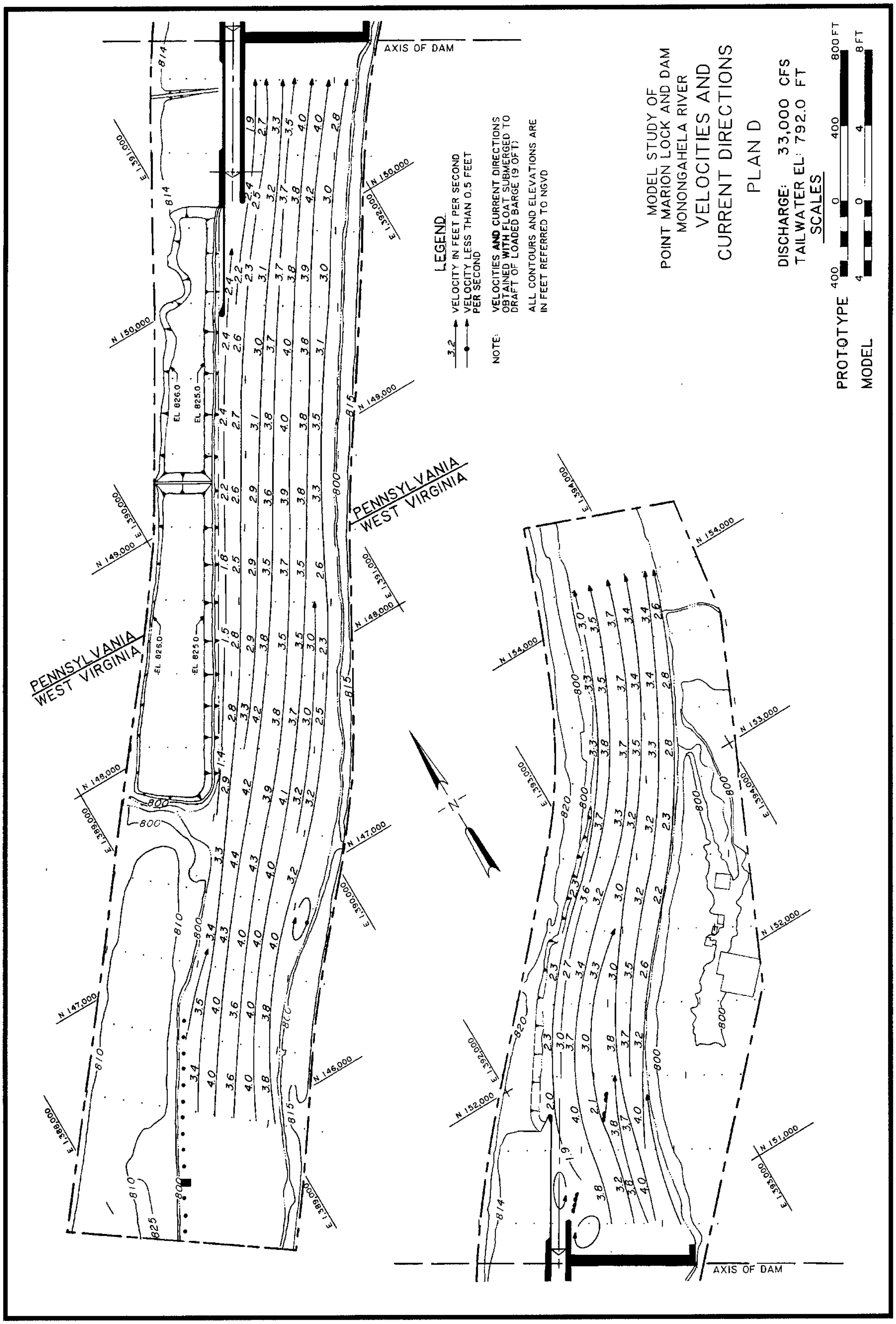
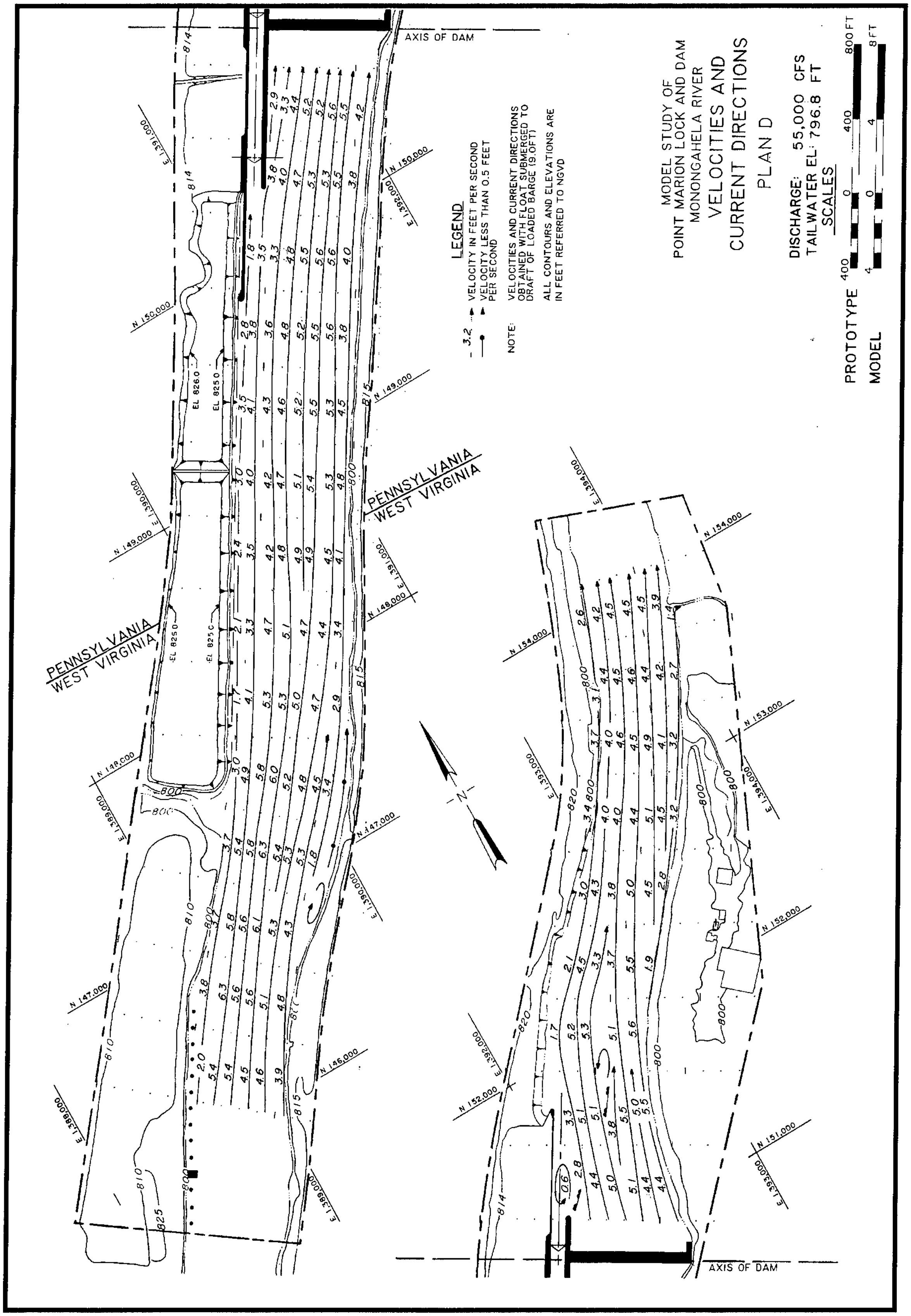
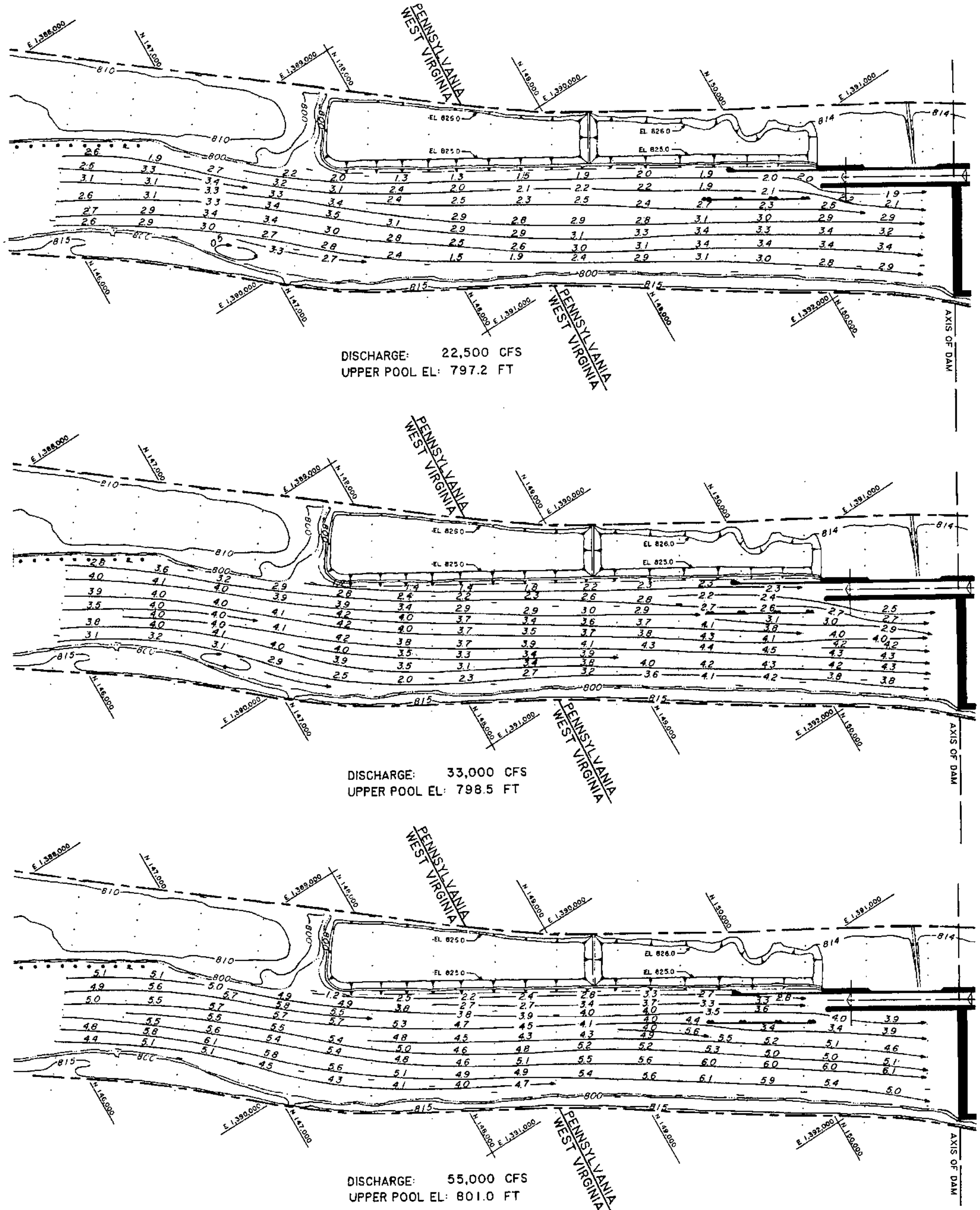

MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER
VELOCITIES AND
CURRENT DIRECTIONS
PLAN D
DISCHARGE: 33,000 CFS
TAILWATER EL: 792.0 FT
SCALES
PROTOTYPE 400 0 400 800 FT
MODEL 4 0 4 8 FT
LEGEND
3.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
AXIS OF DAM
PENNSYLVANIA
WEST VIRGINIA
N

Plate 13



MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER
VELOCITIES AND
CURRENT DIRECTIONS
PLAN D
DISCHARGE: 55,000 CFS
TAILWATER EL: 796.8 FT
SCALES
PROTOTYPE 400 0 400 800 FT
MODEL 4 0 4 8 FT
LEGEND
3.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
AXIS OF DAM
PENNSYLVANIA
WEST VIRGINIA
N
EL 826.0
EL 825.0

Plate 14



MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER

VELOCITIES AND
CURRENT DIRECTIONS

PLAN D-MODIFIED

LEGEND

3.2 → VELOCITY IN FEET PER SECOND
→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 400 0 400 800FT

MODEL 4 0 4 8FT

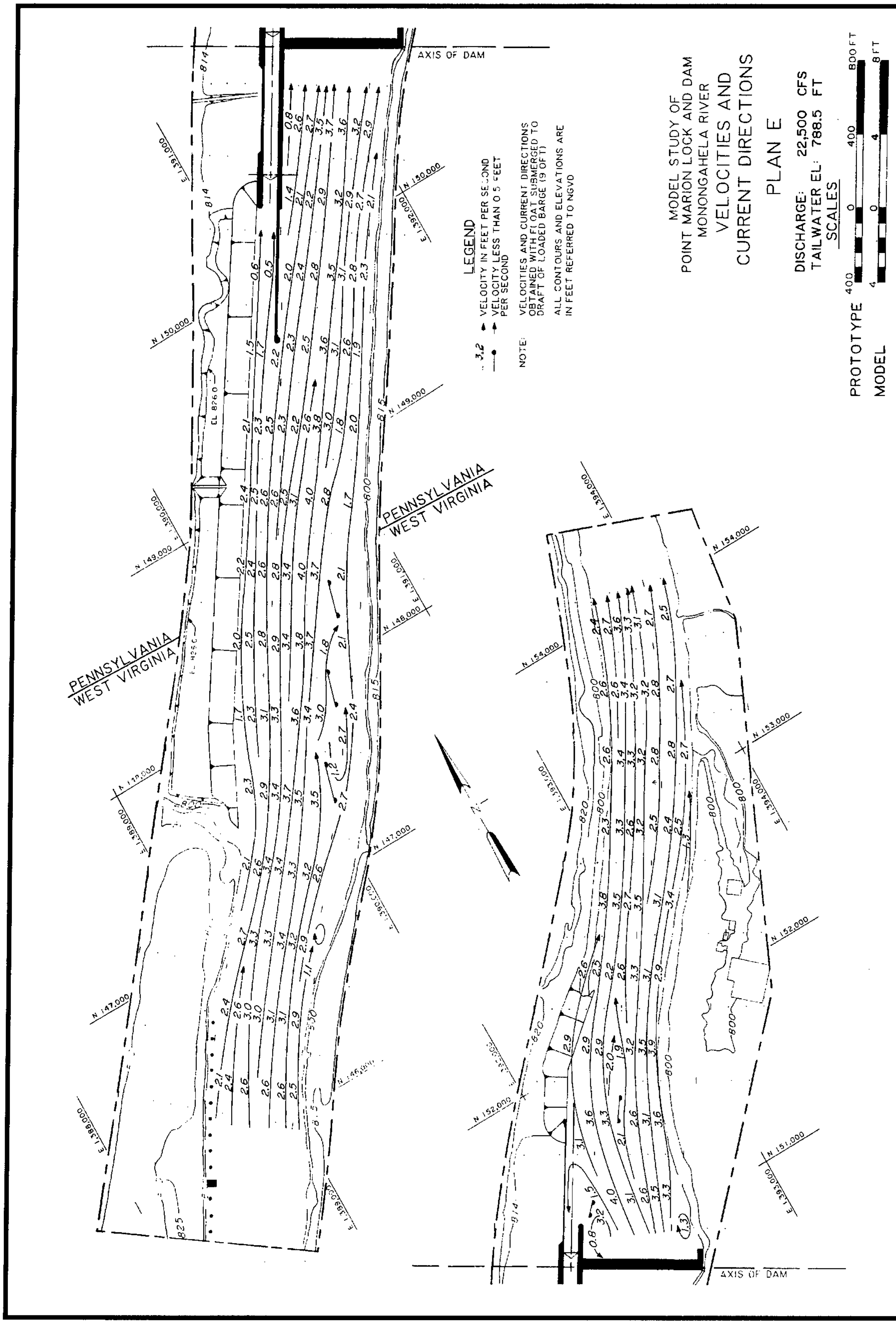
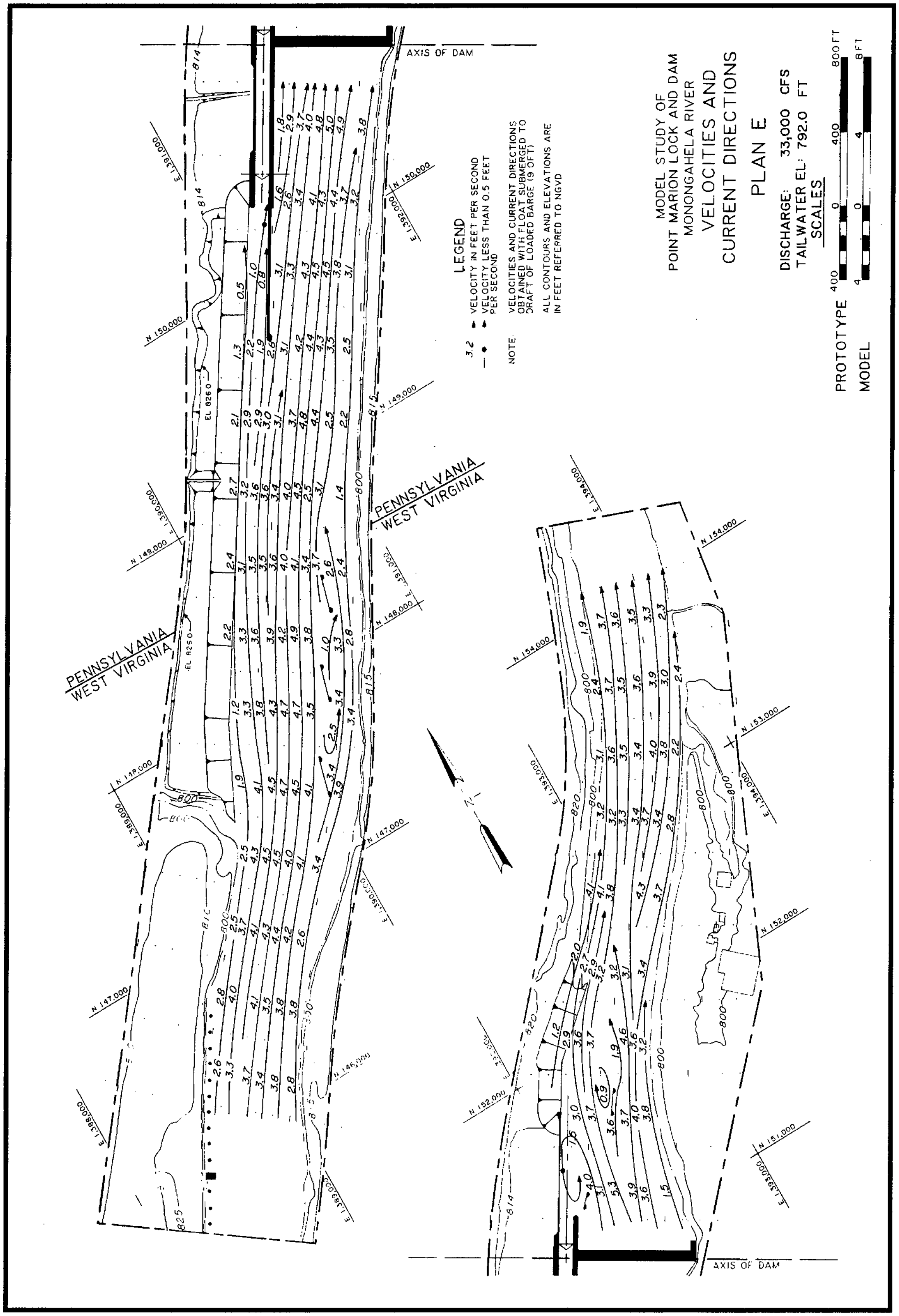

MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER
VELOCITIES AND
CURRENT DIRECTIONS
PLAN E
DISCHARGE: 22,500 CFS
TAILWATER EL: 788.5 FT
SCALES
PROTOTYPE 400 0 400 800 FT
MODEL 4 0 4 8 FT
LEGEND
3.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
AXIS OF DAM
PENNSYLVANIA
WEST VIRGINIA
N

Plate 16



MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER
VELOCITIES AND
CURRENT DIRECTIONS
PLAN E
DISCHARGE: 33,000 CFS
TAILWATER EL: 792.0 FT
SCALES
PROTOTYPE 400 0 400 800 FT
MODEL 4 0 4 8 FT
LEGEND
3.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
AXIS OF DAM
PENNSYLVANIA
WEST VIRGINIA
EL 826.0
EL 825.0

Plate 17

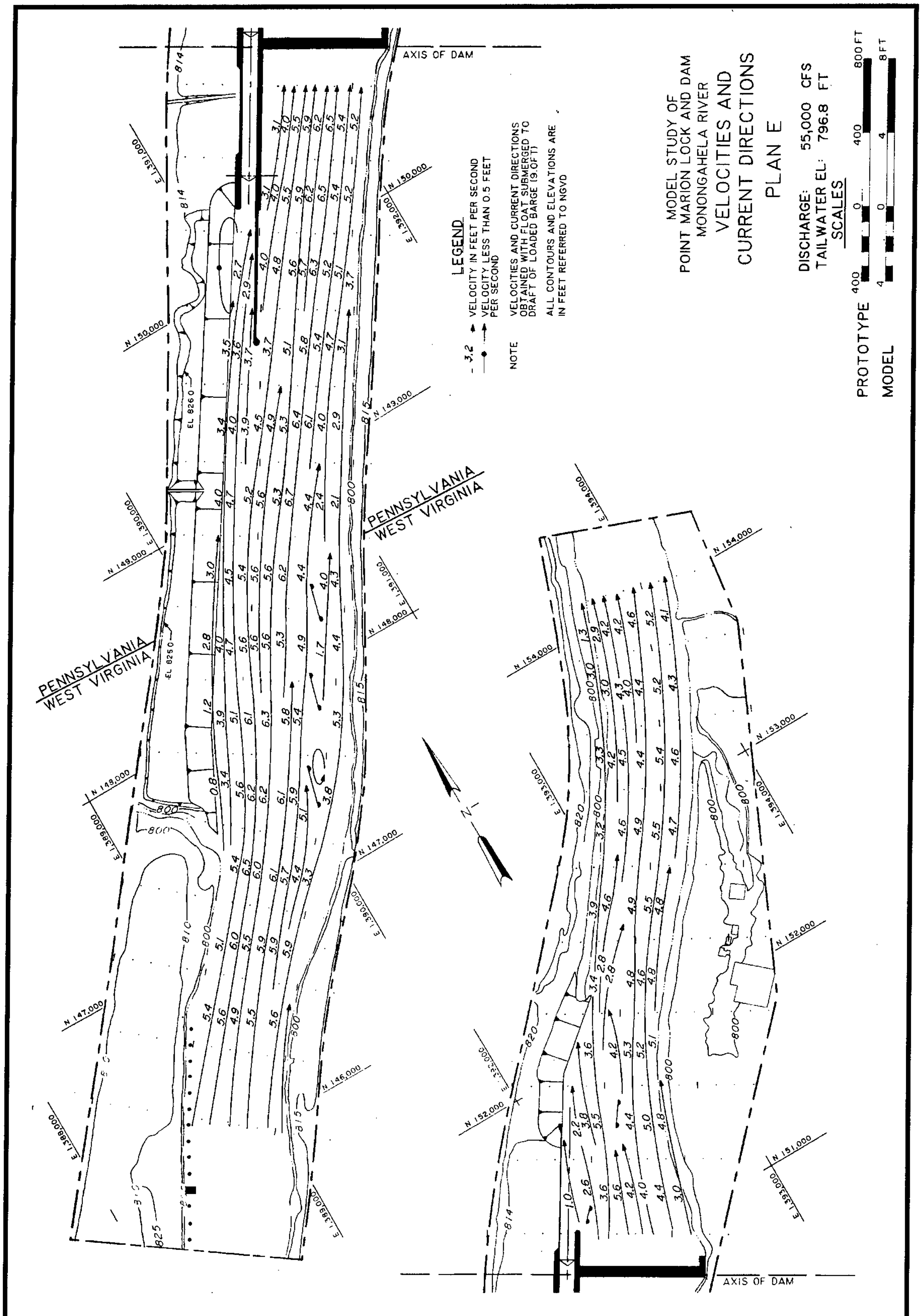
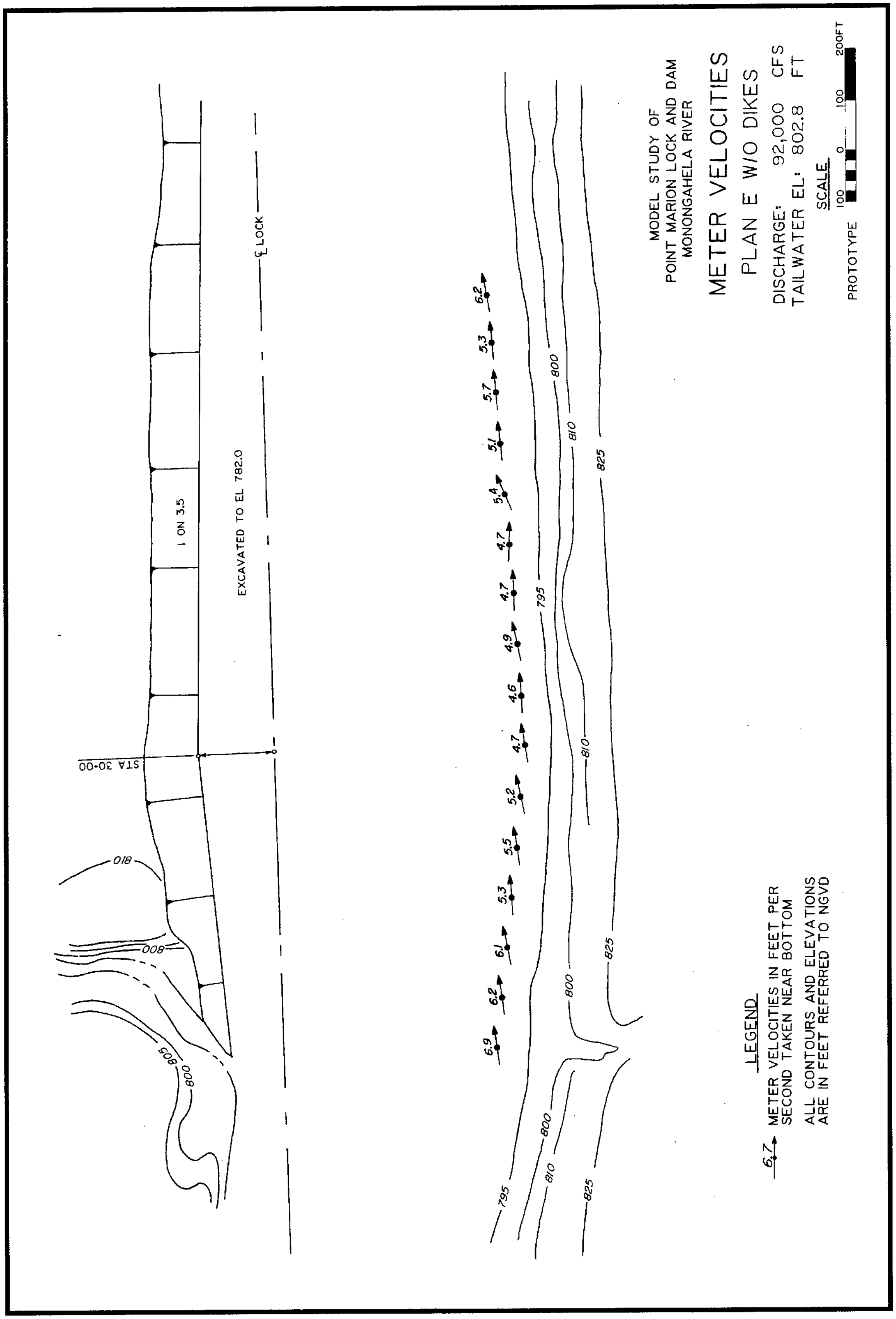
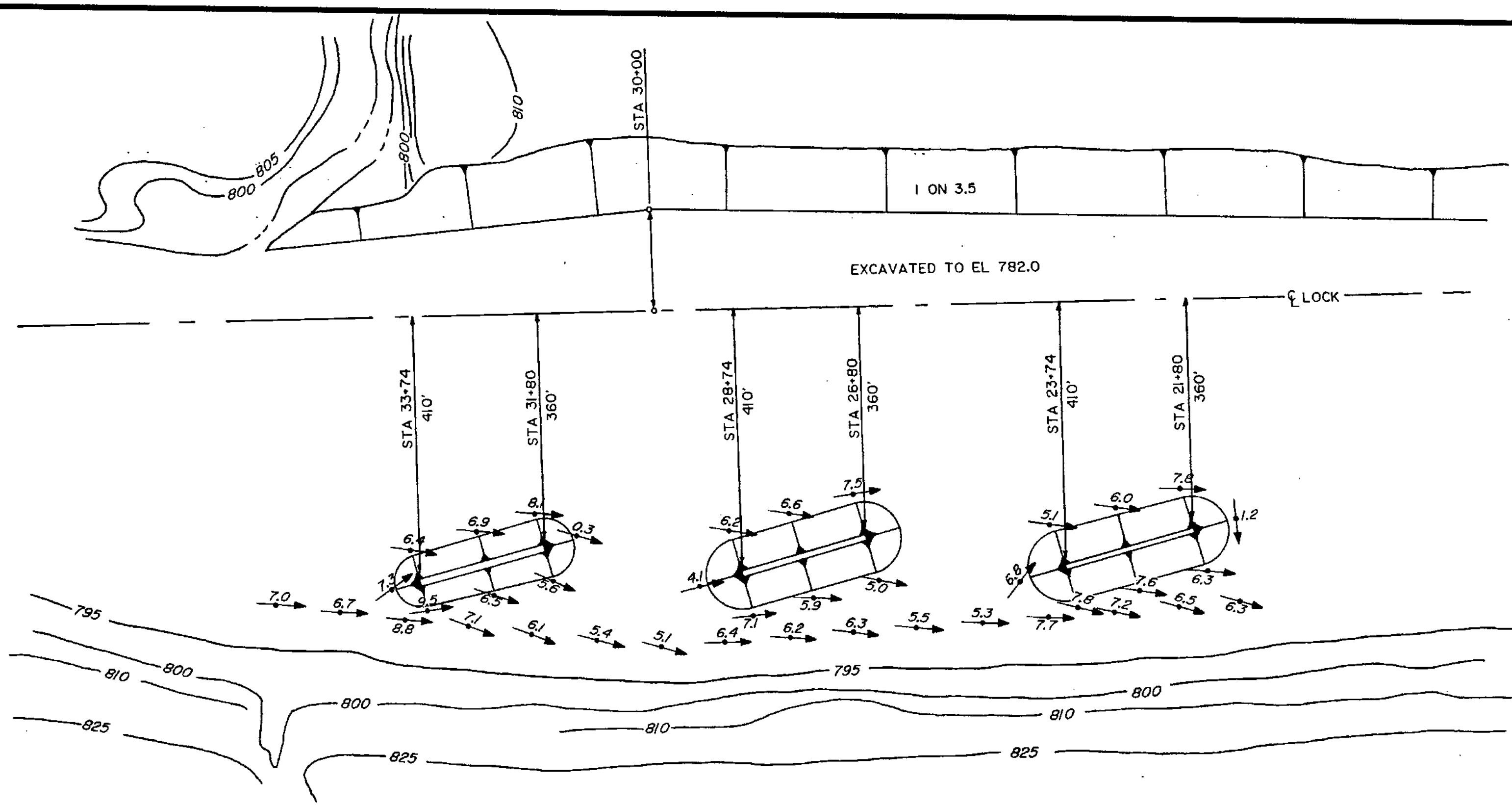

MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER
VELOCITIES AND
CURRENT DIRECTIONS
PLAN E
DISCHARGE: 55,000 CFS
TAILWATER EL: 796.8 FT
SCALES
PROTOTYPE 400 0 400 800 FT
MODEL 4 0 4 8 FT
LEGEND
3.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE
VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
AXIS OF DAM
PENNSYLVANIA
WEST VIRGINIA
N

Plate 18


MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER
METER VELOCITIES
PLAN E W/O DIKES
DISCHARGE: 92,000 CFS
TAILWATER EL: 802.8 FT
SCALE
PROTOTYPE
100 0 100 200FT
LEGEND
METER VELOCITIES IN FEET PER SECOND TAKEN NEAR BOTTOM
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
EXCAVATED TO EL 782.0
1 ON 3.5
℄ LOCK
STA 30+00



MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER

METER VELOCITIES

PLAN E

DISCHARGE: 92,000 CFS
TAILWATER EL: 802.8 FT

SCALE

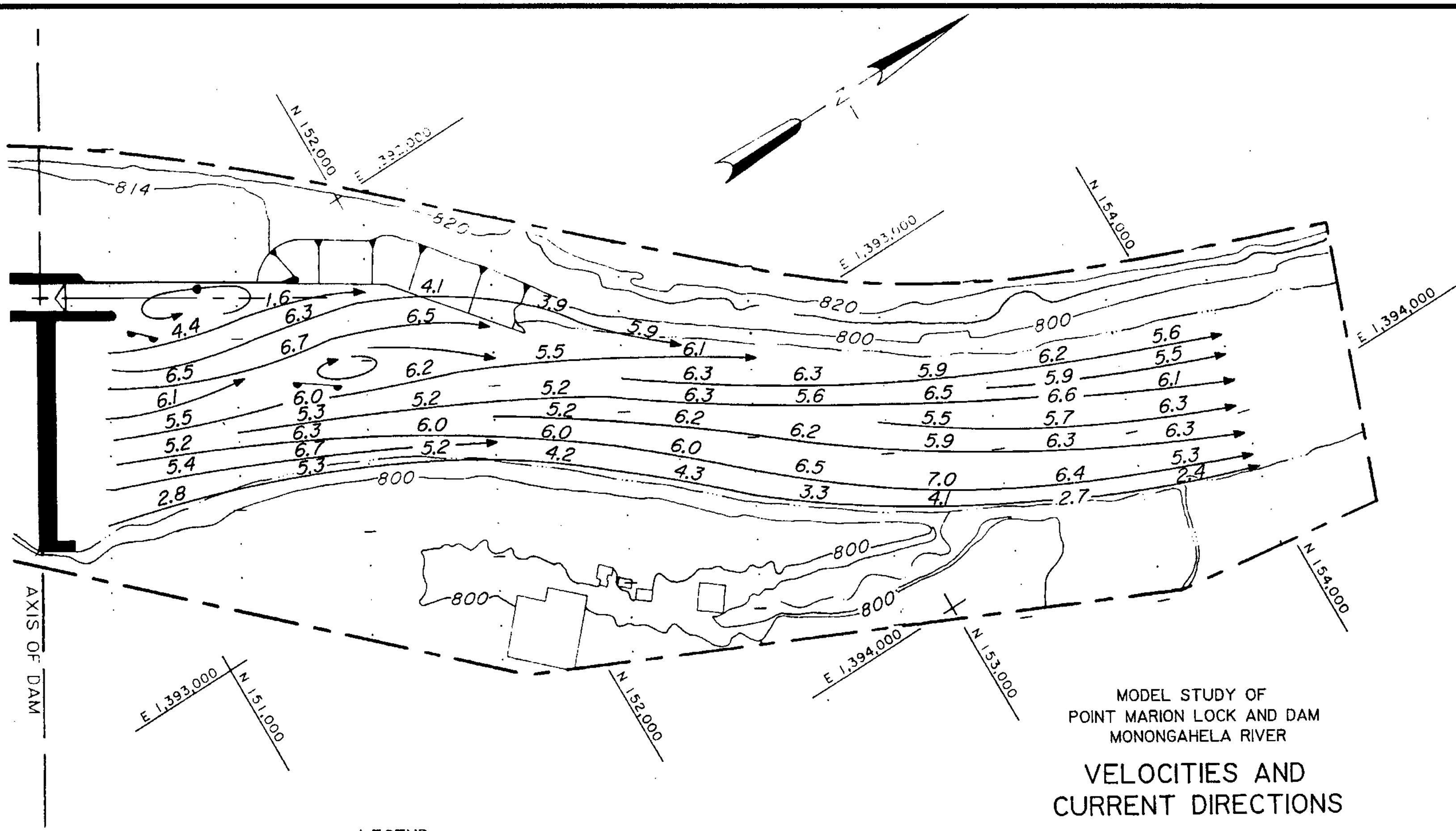
PROTOTYPE 100 0 100 200FT

LEGEND

6.7 → METER VELOCITIES IN FEET PER SECOND TAKEN NEAR BOTTOM

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

Plate 20



MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER

VELOCITIES AND CURRENT DIRECTIONS

PLAN E
DRAWDOWN

DISCHARGE: 55,000 CFS
TAILWATER EL: 791.8 FT

PROTOTYPE 400 0 400 800 FT
MODEL 4 0 4 8 FT

LEGEND

3.2 → VELOCITY IN FEET PER SECOND
—•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

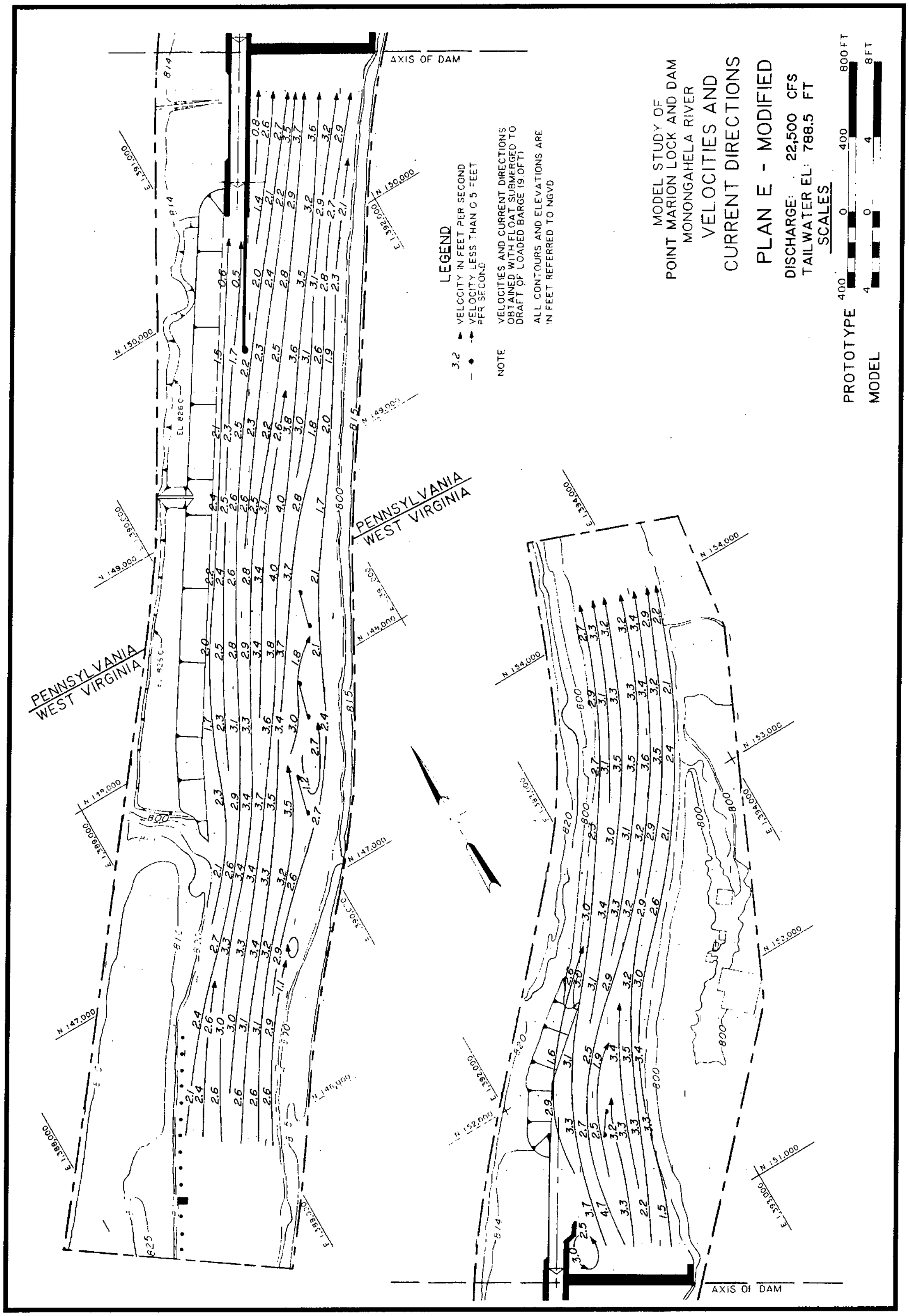

MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER
VELOCITIES AND
CURRENT DIRECTIONS
PLAN E - MODIFIED
DISCHARGE: 22,500 CFS
TAILWATER EL: 788.5 FT
SCALES
PROTOTYPE 400 0 400 800 FT
MODEL 4 0 4 8 FT
LEGEND
3.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE
VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
AXIS OF DAM
PENNSYLVANIA
WEST VIRGINIA
AXIS OF DAM

Plate 22

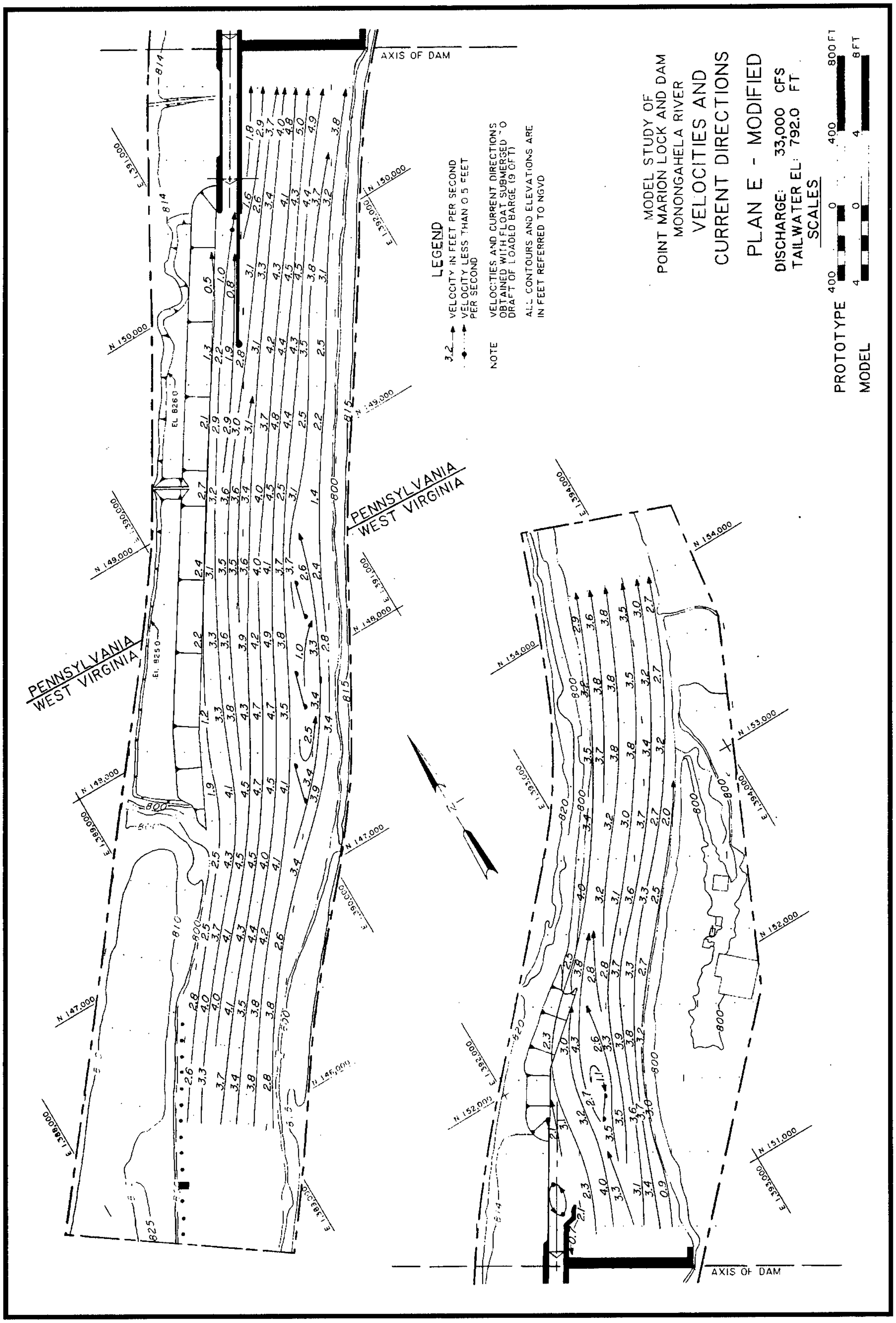

MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER
VELOCITIES AND
CURRENT DIRECTIONS
PLAN E - MODIFIED
DISCHARGE: 33,000 CFS
TAILWATER EL: 792.0 FT
SCALES
PROTOTYPE 400 0 400 800 FT
MODEL 4 0 4 8 FT
LEGEND
3.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE
VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
AXIS OF DAM
PENNSYLVANIA
WEST VIRGINIA
AXIS OF DAM

Plate 23

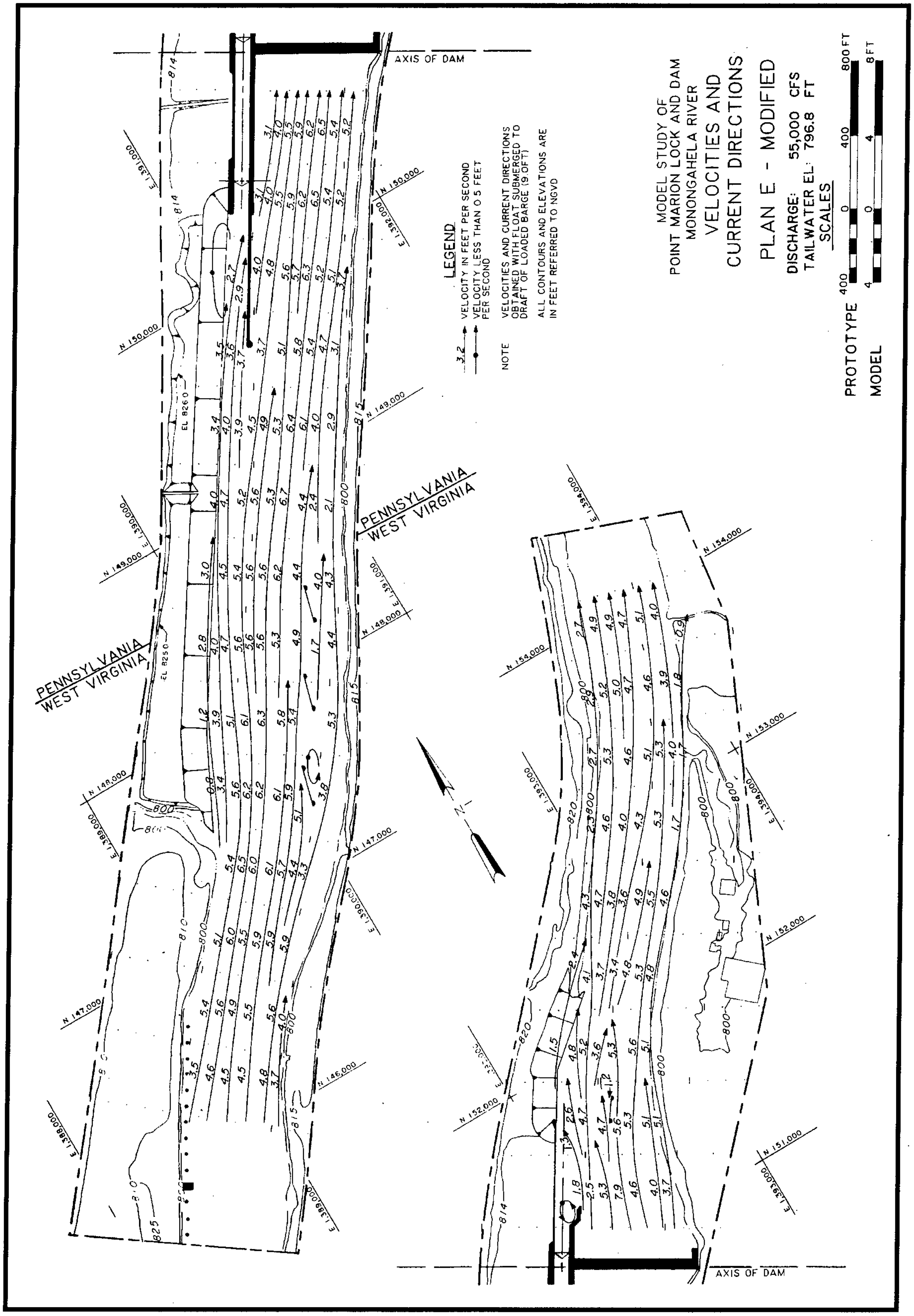
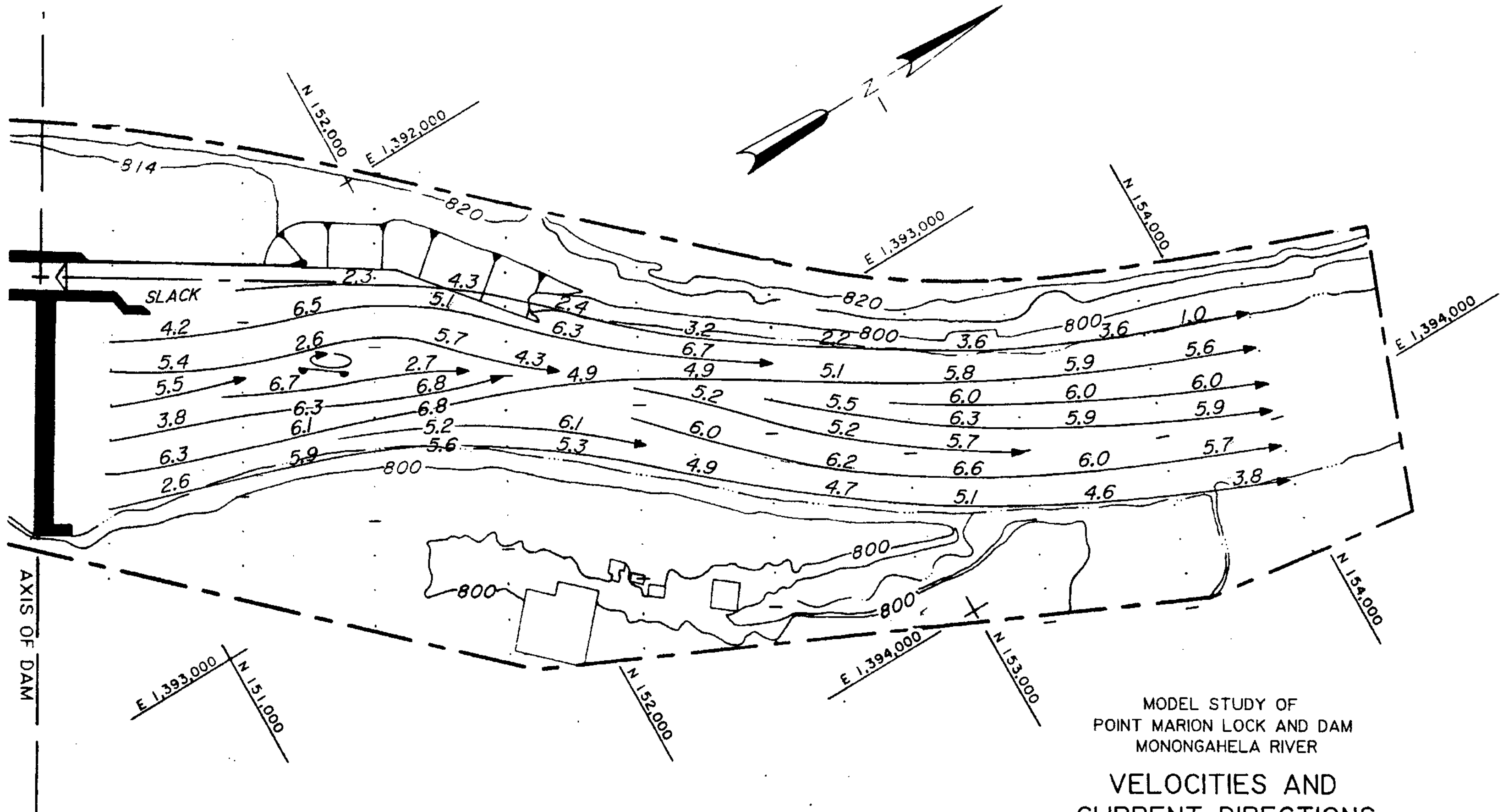

MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER
VELOCITIES AND
CURRENT DIRECTIONS
PLAN E - MODIFIED
DISCHARGE: 55,000 CFS
TAILWATER EL: 796.8 FT
SCALES
PROTOTYPE 400 0 400 800 FT
MODEL 4 0 4 8 FT
LEGEND
3.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
AXIS OF DAM
AXIS OF DAM
PENNSYLVANIA
WEST VIRGINIA
PENNSYLVANIA
WEST VIRGINIA
N

Plate 24



MODEL STUDY OF
POINT MARION LOCK AND DAM
MONONGAHELA RIVER

VELOCITIES AND CURRENT DIRECTIONS

PLAN E-MODIFIED
DRAWDOWN

DISCHARGE: 55,000 CFS
TAILWATER EL: 791.8 FT

PROTOTYPE 400 0 400 800 FT
MODEL 4 0 4 8 FT

LEGEND

3.2 → VELOCITY IN FEET PER SECOND
--•--→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

Plate 25

REPORT DOCUMENTATION PAGE

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Ronald T. Wooley

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12b.DISTRIBUTION CODE

13.ABSTRACT *(Maximum 200 words)*

Point Marion Lock and Dam are on the Monongahela River at river mile 90.8, approximately one mile upstream of Point Marion, PA. The reservoir with normal upper pool el 797.0 (elevations (el) are in feet referred to the National Geodetic Vertical Datum) extends approximately 11.2 miles upstream to Morgantown Lock and Dam. The existing Point Marion project consists of a nonnavigable structure with six crest gates having a clear span of 60 ft between 10-ft-wide piers. A 62-ft-long overflow weir with crest el 796.7 connects the gated structure to the right bank abutment. A 56-ft-wide by 350-ft-long navigation lock is located along the left bank of the river. A fixed-bed model reproduced about 2.1 miles of the Monongahela River and adjacent overbank from about mile 90.0 to mile 92.1 with lock and dam structures to an undistorted scale of 1:120.

The plan for improvement for Point Marion Lock and Dam consists of a new navigation lock with clear chamber dimensions 84 ft wide by 720 ft long to be constructed landward of the existing lock. The existing lock would be removed and the dam would be connected to the new lock by a 115-ft section comprising a 110-ft-long overflow weir with crest el 796.5 and a 5-ft-long section adjacent to the first dam pier with top el 805.0. A new right bank abutment would replace the present deteriorated structure. The existing gated dam would be upgraded. The model investigation was concerned with the

(Continued)

14.SUBJECT TERMS

Fixed-bed models	Monongahela River
Hydraulic models	Navigation conditions
Locks (Waterways)	Point Marion Lock and Dam

15.NUMBER OF PAGES
119

16.PRICE CODE

17.SECURITY CLASSIFICATION OF REPORT	18.SECURITY CLASSIFICATION OF THIS PAGE	19.SECURITY CLASSIFICATION OF ABSTRACT	20.LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		

13. (Concluded).

evaluation of selected plans and development of satisfactory navigation conditions for tows using the project. Results of the investigation revealed that a ported upper guard wall and an excavated channel were required to provide satisfactory navigation conditions for tows entering and leaving the upper lock approach. The investigation also showed that a lower approach plan similar to Plans E or E-Modified would provide satisfactory navigation conditions for tows entering and leaving the lower lock approach. However, downbound tows were required to rotate the head of the tow away from the lower guide wall about 15 deg before leaving the lower approach.